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The Foundry Trades' Equipment and Supplies Association

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Business Conditions at Short and Long Range

Public speakers are beginning to make references to the time when rearmament will no longer be the dominating factor in the industrial activities of Great Britain, and they are directing attention to the need for cultivating overseas markets. The developments of the post-war period have profoundly affected both the nature and the channels of business. Civil engineering is not so great in volume, as road transport has eliminated the construction of what in pre-war days would have been branch railway lines, with their attendant bridges and tunnels. Road-making implements, however, are and will be in greater demand than ever.

An outstanding feature in future business must be the recognition of the fact that because of quantity-production methods of manufacture, many countries are of themselves too small as economic units to undertake such work. The conditions in Belgium, Holland, New Zealand, and most of the Balkan States are not such as to warrant the production of many types of articles unless there is more than a sporting chance of a healthy export business. This must be contrasted with the enormous potential domestic markets of the United Kingdom, United States, Germany, France and certain other countries. Yet there must be a recognition that the requirements of overseas markets do not always align themselves with what is deemed satisfactory for domestic consumption, and if serious business is to be undertaken intelligent modifications must be made.

The next factor is Oriental competition, for, granted something like parity of quality, the European and American working population cannot and must not be expected to compete with the rice-eating peoples. That is where the politicians of the Western Hemisphere must get together.

The immediate problem is one of currency restriction, and at the moment the only solution to be found is that of bartering. The import houses of Great Britain should be alive to this, and help the manufacturer by seeing that, instead of sending sterling to such countries against their purchases of dates, ginger, tobacco leaves and the like, they export the products of our manufacturers. We are aware of engineering houses being offered many strange transactions with Balkan and South American countries, yet deflected into the suitable channels, profit can accrue to both sides, which, we should imagine, will tend in the long run towards the resumption of normal business. A commercial representative visiting many foreign countries must, if he wants to pay his expenses, be prepared to buy his quota of those countries' exportable surpluses. To illustrate how restrictive some of the currency laws are in practice, we have only to cite a case, which came personally to our notice, of a young German in Scotland receiving permission to replace an irretrievably damaged jacket, providing his "exchange" British youth in Germany bought a new pair of boots! Surely it cost the Government concerned more money in "red-tape" than the transaction was worth.

A matter still insufficiently appreciated by manufacturers in this country is that an important group of the smaller European countries have arranged between themselves commercial treaties so as to create a rather important economic entity.

Cavitation Erosion

Cavitation erosion of metals is a type of metallurgical failure which has not been extensively studied. Since cavitation was first noted in marine propellers more than 40 years ago, much work has been carried out on the efficiency of propellers, and a theory has been advanced for cavitation phenomenon. Cavitation erosion, however, is not confined to marine propellers, but extends to other units such as pump impellers and hydraulic turbines. The large developments which have taken place during recent years in hydro-electric schemes have necessitated a wider knowledge of cavitation, and research work has been extended to the cavitation erosion of metals and alloys in order to determine the relative resistance of materials to this type of failure and to supply data for the selection of suitable alloys for particular units.

Until recently, cavitation experiments on metals were carried out on a large scale which not only involved considerable expense, but also occupied long periods of time. The introduction of small experimental apparatus, whether of the venturi tube, water jet, or vibratory type, using small test specimens, has reduced the experimental time to a matter of minutes and has made it possible to carry out extended investigations covering a large number of metals and alloys. Such investigations have been made principally in Germany and in the United States.

In America, the results of two cavitation researches have been published recently, and are of particular interest to foundrymen and metallurgists as they include data on a large number of cast metals and alloys, both ferrous and

non-ferrous. In the tests carried out at the Massachusetts Institute of Technology as part of a large corrosion investigation in connection with the Passamaquoddy Tidal Power Development at Eastport, Me., some 80 alloys were tested in a vibratory apparatus, and 50 per cent. of these were cast. Similarly, in a research sponsored by the Safe Harbour Water Power Corporation, 250 metals were tested, of which one-third were cast irons, cast steels, and cast non-ferrous alloys.

The results of these experiments have not only confirmed that the erosion or pitting that accompanies cavitation action is of a mechanical nature, but have also shown the properties which may be developed in metals to make them more resistant to this type of attack. The necessity of metals and alloys having either a high initial hardness, with satisfactory toughness, or susceptibility to considerable work-hardening, with good initial hardness, is established, as is also the influence of grain size on the resistance of alloys to cavitation. As all these properties can be controlled by casting conditions, addition of special elements, or by heat-treatment, the importance of such work to the foundryman and metallurgist cannot be neglected. The fatigue resistance of metals and alloys is also important, and in this connection, as a result of the recent cavitation experiments, the term "cavitation-fatigue" has been suggested for the conditions involved in this type of failure, and in order to meet such attack, the necessity of having material with good physical and metallurgical properties, including high fatigue resistance, good homogeneity, and freedom from inclusions has been stressed. It has also been shown that the data obtained from cavitation tests can be used as a guide for selecting materials exposed to water drop or water-jet impact, and this is important in the construction of water turbines and low-pressure steam turbines.

National Physical Laboratory

At the annual inspection of the National Physical Laboratory by the General Board, which took place last week, exhibits relating to the following subjects were shown to the visitors in the Metallurgy Department.

The electrolytic method of preparing pure iron formerly employed at the Laboratory failed to remove traces of certain elements, especially nickel. A chemical method of preparation has now been adopted. Purified ferrous chloride is decomposed by steam at a carefully regulated temperature, and the oxide so formed can be washed free from the chlorides or other metals by means of water. The dry oxide is reduced in hydrogen, and is subsequently melted, first under slightly oxidising conditions, then in hydrogen, and finally *in vacuo*. The melting of iron without contamination has been made possible by the use of the high-frequency furnace and the production of special refractory material. Pure magnesia has been found most suitable for crucibles for the oxidising melting, and pure alumina for the final operation. The apparatus and refractories which have been developed for this work were on view.

A furnace was shown which enables the optical determinations of temperature to be made accurately. Pure alumina is used in the construction of the furnace, and the design of the gas burner has been improved so that a temperature of 1,900 deg. C. may be reached without difficulty. Furnaces of similar construction are also used for firing the refractory vessels which are required for the work of the Department.

A combination of the Rosenhain plotting chronograph, with the automatic potentiometer designed in the Department, was on view. This apparatus provides a means for the completely-automatic plotting of cooling curves over a wide range of temperature.

Correspondence

[We accept no responsibility for the statements made or the opinions expressed by our correspondents.]

Some Factors in Sand Testing

To the Editor of THE FOUNDRY TRADE JOURNAL.

SIR,—In the issue of THE FOUNDRY TRADE JOURNAL, dated June 23, you published a letter from Mr. W. Y. Buchanan pointing out that the method of preparing a cylindrical sand test-piece by double compression, as given in my Paper entitled "Some Factors in Sand Testing," which appeared in the issues dated June 9 and June 16, does not agree with that originally described by Mr. Buchanan. This is perfectly true, but gives no indication of what has happened in the meantime.

The core-boxes used by Mr. Buchanan in his original experiments, and described in his Paper entitled "Sand Testing in the Foundry," which appeared in the Proceedings of the Institute of British Foundrymen, Vol. XXV, were wooden

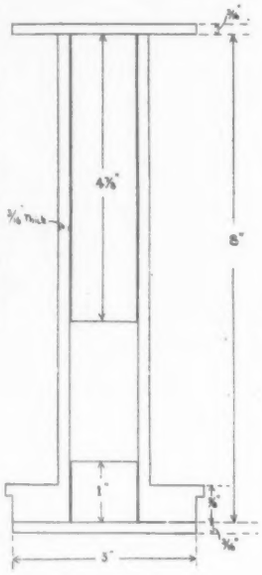

FIG. A.

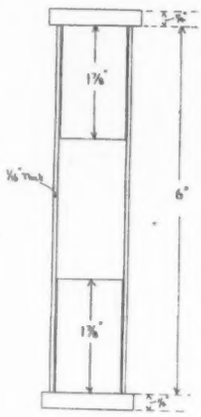

FIG. B.

split core-boxes having two plungers with lengths of 5 in. and 1 in. and a number of distance pieces $\frac{1}{16}$ in. thick. Fig. A illustrates a metal tube with metal plungers which was purchased a few years ago from a British company specialising in the manufacture of sand-testing equipment, and supplied for the preparation of test cylinders by the Buchanan double-compression method. Its dimensions agree very well with those of Mr. Buchanan's core-boxes, but as the tube is in one piece, the test cylinder must be pushed out instead of being lifted out as was possible with Mr. Buchanan's split boxes. Fig. B illustrates another metal tube purchased this year from a British supplier of sand-testing apparatus and intended for the same purpose. It will be seen that the length of the tube and the lengths of the plungers are substantially different from those of Fig. A. There is also on the market another tube even shorter than that shown in Fig. B. In the short tubes the sand for making the test cylinders has to be pressed in the tube by hand before the upper plunger can be inserted, so that there is some squeezing of the sand in preparing the cylinder. The compression of the sand is usually completed by means of light blows at either end, and the cylinder is pushed out of the tube by a separate ram.

It is quite evident that the method of preparing the cylinders is different in each of these cases, and it is not to be expected that all these

(Concluded in next column.)

Random Shots

A distinctly novel note in publicity has been struck by the Beardsley & Piper Foundry Equipment Company, of Sandslinger fame, in the publication of correspondence between Mr. Piper and "Lon," the King Pin of the firm's publicity department, during the former's tour of foundries around the world. "Lon" is obviously a stamp collector, and "Marksman" wonders if he really badgered Mr. Piper into making this trip in order to augment his collection with a few good air mails, for stamp collectors are notoriously rogues where their hobby is concerned, however blameless their life in other spheres. It is fortunate, however, for lovers of stamps that not all the world's issues are printed in red and blue (with no variations in shades) as on the cover of this admirable booklet. Mr. Piper, during his trip, had ample opportunity of proving the truth that foundry-work and culture go hand in hand. A primitive people beget primitive foundries, so that at the bottom of the scale one sees foundries in which are used goatskin furnace blowers with bamboo pipes, at the other end the highly mechanised equipment of the most modern American workshop. What foundryman would not wish to have the same opportunity as Mr. Piper of seeing foundries of all countries, not to mention of experiencing all the attendant delights of trotting around the globe, to which delights Mr. Lon refers more than once with envy in his heart!

* * *

The brains of the Lake City Malleable Castings Company of Cleveland, Ohio, are obviously as pliable as the neck of their famous flamingo, a little ornament which, by the way, decorated the Editor's desk for some years. Their latest idea is to run about the country with their samples of castings in a trailer. With this formidable weapon they intend to "fight the recession doldrums," having rightly come to the conclusion that business doesn't come to him who sits around and waits. The idea of hawking castings round in this manner is certainly novel, though one has heard of moulding machines being sold from a travelling lorry, and the demonstration vans of the gas and electric supply companies are already a familiar sight on the roads.

* * *

The idea has possibilities. At exhibitions, exhibitors' work would be reduced to a mere matter of running the trailer on to the stand and installing the soda fountain inside it.

* * *

Carrying the idea to an extreme, a portable foundry could be rigged up on a lorry and used for roadmaking, so that cast-iron sets could be made on the spot.

"MARKSMAN."

(Concluded from previous column.)

cylinders would give the same green strength at the same relative density when prepared from the same batch of sand, although from the results of experiments I think the differences are less than Mr. Buchanan fears.

To my mind, the facts that these metal tubes are far more widely used than Mr. Buchanan's split core-boxes, and that the method of preparation does vary from foundry to foundry, merely emphasise the statement made in my Paper, that it is high time that conditions of sand testing were standardised throughout the country. The need for such standardisation has been recognised by the British technical committees concerned with sand testing, and a new committee to make recommendations for this very purpose has recently been set up by the technical institutions most interested in the problem.—Yours, etc.,

T. R. WALKER.

"The Priory," Oughtibridge,
near Sheffield.
June 28, 1938.

The Modern Manufacture of Machine-Tool Castings*

By J. BLAKISTON, A.I.Mech.E.†

The object of this Paper is to present, in a manner necessarily brief, a survey of present-day practice and developments which are taking place in the production of machinable grey-iron castings for machine tools. Numerous valuable and interesting Papers covering such subjects as camber, densening technique and use of special irons have been written concerning machine-tool castings, indicating the numerous problems encountered and the endeavours made by the foundry to meet the rapid progress in the design and construction of modern machine tools.

Machine-tool castings vary in weight from a few ounces to 50 tons and over, the section varying in thickness from $\frac{3}{16}$ in. to 9 in. and over, with section variation of this order sometimes occurring in the same casting. Most machine-tool castings require to be machined internally in addition to externally, the machined faces of which remain exposed to view in the completed machine and must be free from all forms of defects and blemish. The machined faces not exposed are generally slide-ways, and in addition to being free from any form of defect must be close-grained, possessing good Brinell hardness value to resist wear.

Cast iron possesses many certain, definite advantages which, while making an ideal material to use for the construction of machine tools, preclude the likelihood of its being superseded by any other material, provided full advantage is taken of developments that are constantly taking place in its manipulation. The following are the outstanding properties of cast iron which commend it to the machine-tool manufacturers.

Ease of Casting to any Desired Shape

The various parts of a machine tool may be of extremely complicated shape and the present trend towards cellular construction with diagonal bracing (sometimes called the Allen system) makes the casting process the only economical way of producing these shapes. Taking the cost of the pattern and moulding tackle into consideration, each further unit made from the original pattern is necessarily cheaper. This advantage can be coupled with that of low production cost.

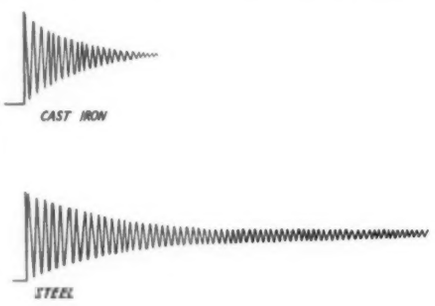

FIG. 1.—FOEPPL-PERTZ DIAGRAM.

Low Production Cost

The cost of the castings, even when in alloy iron, is rarely more than 20 per cent. of the cost of the finished machine. This aspect should be given serious thought, for when so much time and labour is spent on the subsequent operations on the castings, a small increase in the first cost to produce a superior foundation material is justified.

Rigidity

This property is essential in a machine tool, as the accuracy of the work which it has subsequently to produce depends on its ability to retain its shape when subjected to varying stresses. Cast iron generally can be subjected to a stress equivalent to 80 per cent. of its breaking load without taking permanent set. This property is an advantage in the case of a machine receiving an abnormal violent shock stress, when a breakage may result in place of an undetected deformation or distortion which would occur in a more ductile material. Attention has also been focused on the advantage of cast iron by the notable failure which has attended any attempt to replace iron castings by steel welded structures for machine-tool frames

MR. J. BLAKISTON.

Capacity for Absorbing Vibration

This is a very important property of cast iron, and has only recently come to the notice of machine-tool designers, mainly through the introduction of higher speeds occasioned by the use of modern cutting tools. The higher cutting speeds of the modern alloy carbide tool over that of carbon steel tools has resulted in an increase of stress repetitions by as much as twenty times.

The vibration absorption properties of metals can be measured by means of the Foeppl-Pertz machine, and the record traced by this machine gives a very graphic indication of the vibration damping properties of the materials so tested. Fig. 1 shows a record taken from this machine, and Fig. 2 shows the properties of aluminium (which has about the best vibration absorption properties), common cast iron, high-duty cast iron and mild steel. It will be seen from this chart that the stronger the iron, the less is the apparent damping effect. This would indicate that certain castings for machine tools, *e.g.*, trays, legs, supports in compression, should be made from softer cast iron on account of their extensive damping effect. This property has been dealt with in considerable detail in a Paper* read by Smalley.

Low Coefficient of Friction

Cast iron is one of the few materials which forms a good bearing with itself in its natural or untreated form. This can be attributed mainly to the presence of graphite flakes. For bearing surfaces subject to high pressures, the introduction of nickel and chromium is found to assist materially.

The above are only a few of the advantages of cast iron. It is not proposed to detail such properties as machinability with high Brinell value, ability to take a fine finish, resistance to corrosion, etc., all of which are valuable properties of cast iron in the construction of machine tools.

Three Grades

Cast iron as used in machine-tool construction can be divided conveniently into three grades:—(1) General engineering cast iron (straight pig and scrap mixture, giving 1.0 per cent. phosphorus); (2) high-duty steel or refined iron mixture (medium phosphorus); and (3) low total-carbon alloy cast iron. Typical compositions of these three types are shown in Table I.

TABLE I.—*Typical Percentage Compositions of Cast Iron Used in Machine-Tool Castings.*

	1.	2.	3.
Total carbon	3.3 to 3.5	3.0 to 3.2	2.9
Silicon* ..	1.1 „ 2.5	0.9 „ 2.25	2.0
Manganese ..	0.6 „ 0.8	0.6 „ 1.0	0.8
Sulphur ..	0.10	0.10	0.09
Phosphorus..	1.0	0.70	0.15
Nickel ..	—	—	1.2†

* Depending on section. † "Ni-Tensyl."

Properties of Machine-Tool Castings

The following is a brief description of the various properties to be expected from these irons.

(1) *General Engineering Irons (Phosphoric).*—This class of metal covers the type of iron used for machine-tool castings over a long period of years, and, although termed phosphoric, is not to be confused with the higher phosphorus metal of the light casting industries.

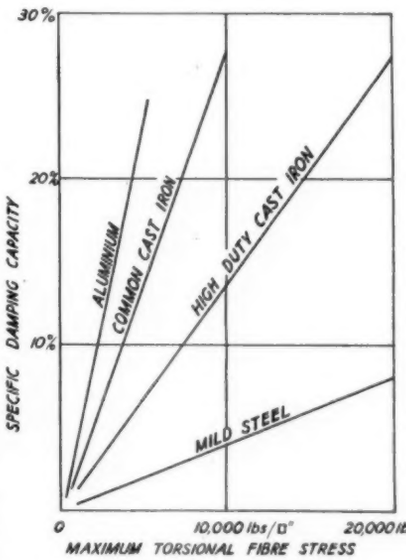

FIG. 2.—VIBRATION ABSORPTION CAPACITIES.

Fig. 3 shows a typical photomicrograph of this class of iron. It will be noted that the graphite is medium-coarse in flake formation, with the matrix mainly pearlitic and the phosphide present as large areas in a coarse network. This class of iron still has many adherents, mainly on account of its fluidity and generally good casting properties. A characteristic of this iron is, however, that it tends to show rather open grain in heavy sections, with a low Brinell hardness

D

* Paper presented at the Annual Conference of the Institute of British Foundrymen in Bradford.

† Manager, Modern Foundries, Limited, Halifax.

* "Gear Castings with Special Reference to Cast Iron," FOUNDRY TRADE JOURNAL, July 22, 1937.

value of the order of 140. Tensile strength value on separately cast bars, 1.20 in. dia., is of the order of 10 to 14 tons per sq. in.

To obtain a closer grain in heavy sections and so meet the present-day standards set for machine tools, densening is resorted to with reasonable success. The technique of the use of denseners as an aid to the production of machine-tool castings has been dealt with in a Paper by E. Longden. For the smaller medium-light section type of machine-tool castings, this class of metal still offers considerable scope, and good wearing properties are amply demonstrated by the fact that there are many machine tools still in operation after 30 to 40 years' useful life.

FIG. 3.—ORDINARY PHOSPHORIC CAST IRON. ETCHED PICRIC ACID. × 100.

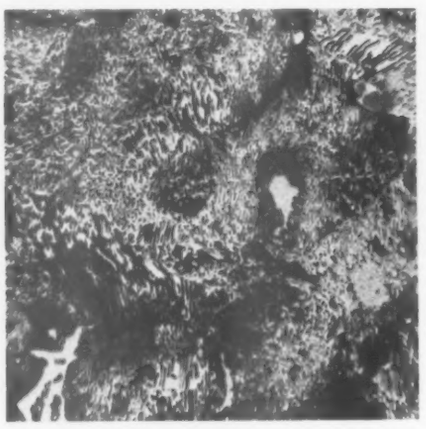

FIG. 4.—HIGH-DUTY CAST IRON. ETCHED NITRIC ACID. × 500.

FIG. 5.—ALLOY CAST IRON. × 500.

(2) *High-duty Iron.*—A typical microstructure of this class of iron is shown in Fig. 4 at a magnification of 500. It will be noted that the graphite is present as short stubby flakes in rosette formation. The matrix is dense pearlite with well-distributed small phosphide areas. This structure is taken from the centre of a heavy-section slide of an 8-ton casting, not densened in any way. A Brinell hardness value of 200 was obtained on the thickest section after machining.

The composition of this iron is T.C, 2.80; Si, 1.75; Mn, 0.70; S, 0.07, and P, 0.70 per cent. The carbon content is somewhat lower than is desirable for large castings; with a carbon content of below 3.0 per cent. there is a tendency to irregular camber and contraction, with a corresponding possibility of cracking. The tensile strength of this casting (cast-on test-piece) was 18 tons per sq. in. With high-duty iron densening is seldom resorted to, except to compensate violent changes of section or hot spots which occur through design. With these irons of medium-low carbon content, the presence of phosphorus up to 0.70 per cent., on account of its influence on the running properties, is permissible, and the closer appearance which it gives to the metal when machined outweighs its disadvantages.

(3) *Alloy Irons.*—The principal alloys used are nickel and chromium, the latter often being added to general engineering iron to assist in obtaining a satisfactory Brinell hardness value. Nickel is employed to give a combination of uniform structure in varying sections, together with fine grain and good wearing quality in the castings, whilst maintaining good machinability.

Considerable development has taken place in America in the use of alloy castings for machine tools. The silvery characteristic of the cast iron in American tools has often been commented on. The advantages of alloy cast iron for machine-tool castings is rapidly being recognised in this country.

The photomicrograph reproduced in Fig. 5 was taken from a typical modern nickel alloy cast iron as made by the "Ni-Tensyl" process. This iron lends itself particularly to machine-tool production, giving a tensile strength of 22 tons per sq. in. and upwards, with a Brinell hardness of 240 to 280, accompanied by good machining properties. As shown in the photomicrograph, the iron has a dense, fine structure, with fine graphite flakes embedded in an all-pearlitic matrix.

"Ni-Tensyl" is produced under British Patents 290,267 and 352,510, and is essentially a synthetic iron made up from steel scrap and alloy additions with suitable inoculation. This metal is suitable for a wide range of sections.

FIG. 6.—BRACKELSBERG FURNACES.

Melting Practice

The cupola is still, and is likely to remain, the principal melting unit for machine-tool castings, on account of its low melting cost, flexibility and ease of manipulation. With the introduction of high-duty and alloy irons more exacting furnace control is essential to achieve the required results, or difficulties will be experienced.

High-percentage steel mixtures are used, which tend to be more severe on cupola linings and, therefore, only first-quality furnace bricks and patching material should be used. The author prefers a lining built from bull-head bricks with their noses pointing into the centre of the cupola, and has found an increase in life of 20 per cent. over a lining made from similar bricks in block form. Correct air volume and pressure control is essential to ensure clean, hot metal with maximum life.

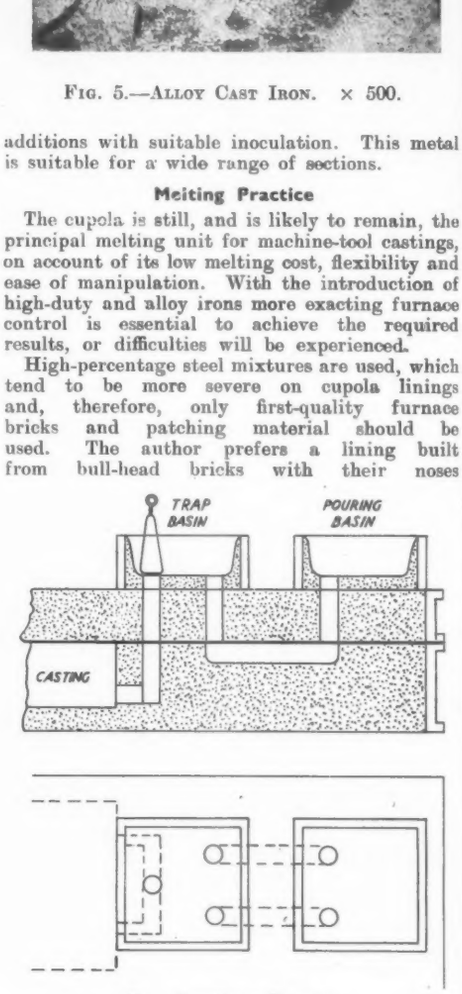

FIG. 7.—TRAP RUNNER.

For the melting of high-duty and alloy irons, coke consumption from an economic point should be a secondary consideration to that of being able to tap the metal at a satisfactory degree of superheat (1,450 to 1,500 deg. C.), and to achieve

this the coke ratio is generally higher than the accepted figure of 10 : 1 excluding the bed. It has been found that high-percentage steel mixtures result in a high sulphur pick-up, and care should be taken to use only best-quality coke.

The Rotary Melting Furnace

This has made considerable progress during recent years, and a combination of the rotary and cupola furnace as a melting unit for machine-tool castings approaches an ideal combination, although where a wide range of casting sizes is being produced, the rotary furnace melting unit alone presents some disadvantages.

In the following remarks the type of rotary furnace concerned is the Brackelsberg (Fig. 6), burning pulverised bituminous fuel, which can be described as the long-flame type. This furnace, apart from rotating, tilts to an angle of 45 deg., so that it can be charged from a platform without the use of a charging machine. The rotary furnace is not a method for producing a cheap iron, but a means of producing a stronger metal, and facilitates obtaining iron with a low carbon content and/or desired alloy content. (The addition of alloys to the ladle is, in the opinion of the author, a practice to be deprecated, except for inoculation effects.) When producing machine-tool frame castings, it is inadvisable to attempt to use 100 per cent. scrap with alloy corrections, for, although the composition may be to the desired limits, an iron liable to crack, and with a tendency to hereditary oxidation, is obtained. When making large castings, a minimum of 30 per cent. pig-iron should be used in the charges, also 30 per cent. of metal melted in a cupola should be added in the ladle to that tapped from the rotary furnace. This general rule should be followed whether duplexing or not.

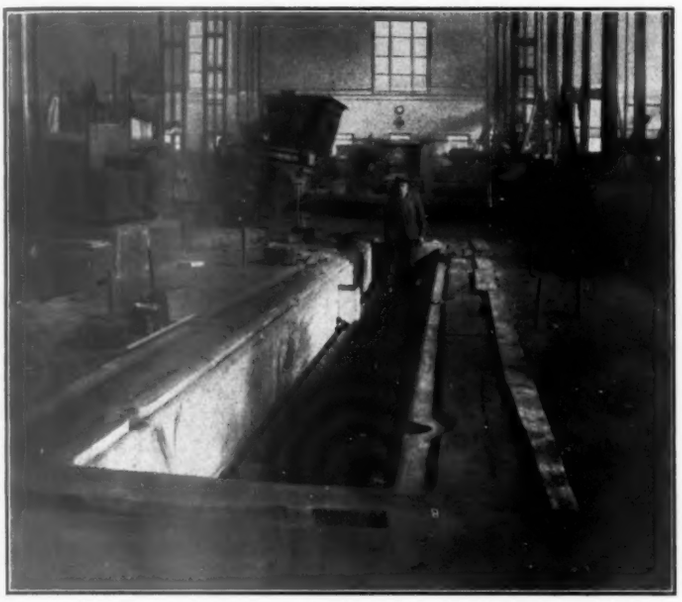

FIG. 8.—MOULD FOR PLANING-MACHINE CASTING.

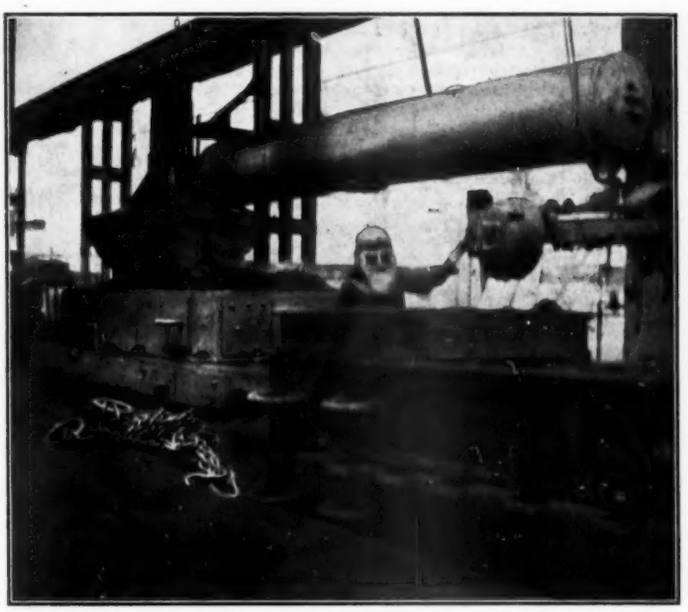

FIG. 9.—SHOCKLESS JARRING MACHINE AND SANDSLINGER.

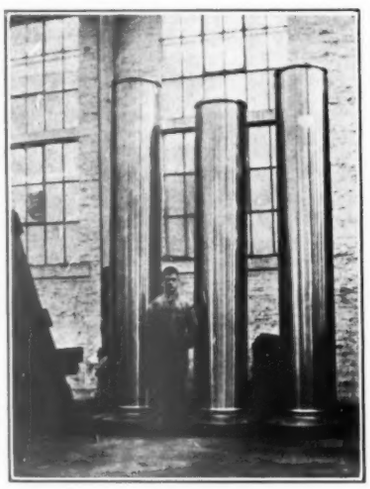

FIG. 10.—DRILLING-MACHINE SLEEVES.

Rotary Furnace Linings

The monolithic lining for rotary furnaces has presented difficulties to users of this class of melting unit. The general practice has been to reline the furnace entirely with a new lining every 100 to 150 heats with furnaces of 10-ton capacity. The following method has been found very satisfactory for lining this type of furnace when operating intermittently.

The casing is first lined with 4½ in. of common firebrick to form a backing. The furnace is then lined with first-class "ganister" by ramming round a former. This "ganister" is used with a free-moisture content of approximately 5 per cent., and is of the following composition:—

		Per cent.
Silica	SiO_2	86.0
Alumina	Al_2O_3	8.0
Iron oxide ..	Fe_2O_3	1.4
Lime	CaO	0.10
Magnesia	MgO	0.30
Potash	K_2O	0.12
Soda	Na_2O	0.38
Loss on ignition..	—	3.36

It will be seen that the silica content is not as high as is usual for rotary furnace linings.

The greatest wear on the furnace lining takes place during charging, and while the furnace and charge are being heated to the normal operating (melting) temperature, and the higher the silica content of the lining material, the greater the contraction and expansion range, rendering the lining more friable under mechanical shock.

"Ganister" with the stated silica content may not be so refractory for extremely high temperatures, but it will patch more easily, and can be maintained on similar lines to a cupola. A 10-ton furnace lined in this matter has given, up to the time of writing, over 300 heats without a major re-line. This type of lining is "active," meaning that the metal has not the tendency to stick to it and become oxidised. This property compares with that of an air-furnace bottom which has to be made up with silver sand every twelve or so heats to keep it "active." To maintain this state in the rotary furnace, after every heat when the slag has been drained out, about 2 cwts. of sea sand is thrown in, while the furnace is kept revolving to distribute it evenly. This frits to the lining.

Melting Losses and Gains

Melting losses and gains of the various elements vary for each individual furnace and with the quality of coal used for firing. The greatest loss of silicon and carbon takes place when the metal charge is in a pasty state. At this period of the melt, it is possible to make any carbon additions necessary in the form of petroleum coke. The carbon is charged into the furnace, and the furnace is revolved so that the metal rolls on top of the carbon like a mat. The furnace is not continuously revolved until the metal is quite fluid. Silicon is added 20 min. before tapping, so that it also acts as an inoculant. The average metal losses may be allowed for as below, but these may vary with conditions, as previously stated:—C, −20 per cent.; Si, −28 to 30 per cent.; Mn, −14 per cent.; S, +0.004 per cent.; and P, no change or slight increase.

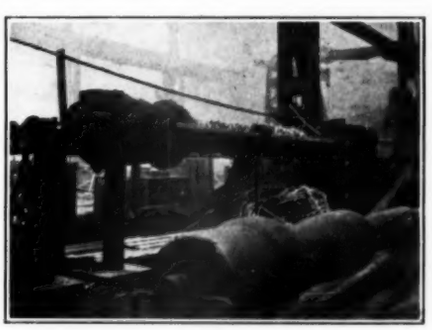

FIG. 11.—CORE BARREL MACHINE.

The following is the comparison of two large planing-machine tables cast from the same pattern, one from cupola melted metal and the other from rotary furnace metal. The physical tests were similar, both giving 17.0 tons per sq. in., with a Brinell hardness figure of 200 on the

heavy section after machining. The metal was perfectly close at the bottom of deep T-slots.

Composition. Per cent.	Cupola metal.	Brackelsberg rotary furnace metal.
T. C	3.40	3.10
Si	1.20	1.5
Mn	0.54	0.80
S	0.117	0.07
P	0.78	0.40

With low total-carbon rotary-furnace metal, the silicon range can be higher and to much wider limits, and still maintain close grain in heavy sections. When duplexing is carried out, the iron with the lower silicon content and any alloy addition is melted in the rotary furnace, and the iron with the higher silicon content is melted in the cupola.

Moulding Methods

Nearly all machine-tool work is of a jobbing nature, and the numbers and size of some of the castings do not permit the general use of mechanical methods of moulding. Two main principles are observed:—Castings must be made with the "ways" to the bottom of the mould, and the casting must be run into the lowest portion, this being generally direct into the "ways." Metal perforated strainers are used on the smaller moulds, and trap runners are used on larger castings similar in construction

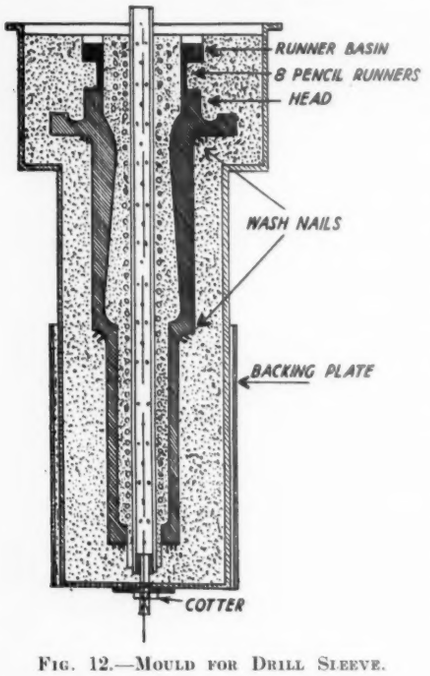

FIG. 12.—MOULD FOR DRILL SLEEVE.

to that shown in Fig. 7. In the moulding of large castings, the flats of the "ways" are strickled, the correct camber, which in some cases may be as much as 1½ in., being allowed for during this process. The pattern is then laid down on this bed, and moulding proceeds.

Camber on machine-tool castings has been very extensively dealt with by E. Longden in one of his Papers entitled "Camber in Castings." The camber of any large casting should be recorded for future guidance, and even then it may vary with analysis variation. Fig. 8 shows a mould 40 ft. long ready to be cored up. In the background can be seen a travelling sandslinger used for ramming the mould tops, and also a portable dryer. In a casting of this size, three or four of these dryers would be used simultaneously for its drying. The mechanical ramming aids for making these moulds are practically limited to the sandslinger and the pneumatic rammer.

On medium routine work, jolting machines can be used to facilitate ramming. Fig. 9 shows an 8-ton shockless jarring machine which is used for preparing drags. The half or block portion is placed on a table and covered with facing sand. The drag is then placed in position and filled with backing sand by means of a grab operated by an overhead crane. After this mould has been jolted, it is turned over and placed under an adjacent sandslinger, which rams the tops. The completely rammed mould is then passed to the moulders for pattern withdrawal and finishing, the mould being dried *in situ* by means of a portable dryer. Very good production times are achieved by this method, but it is only applicable for certain classes of work.

Refractory Materials

It is not proposed to discuss sands in this Paper, as these depend on the geographical situation of the foundry, but it has been stated that high-duty and alloy irons require to be poured at a fairly high temperature on account of their short freezing range. This calls for moulding sands that are refractory, or "burning-on," which creates considerable fettling difficulties, will take place in the heavier sections of the castings.

The following "compo" has been found very resistant to the action of hot metal, and can be applied on the thicker sections of a casting and in the vicinity of the runners:—One barrowful old firebricks; five shovelfuls of fireclay; five shovelfuls of sea sand; four shovelfuls of small coke; one bucketful of common blacking. These are milled, and water is added until the required fineness and degree of moisture for ramming is obtained. It can be let down still further with water and used in the place of loam for strickle work.

Drilling-Machine Sleeves

The following describes in more detail the methods of moulding a typical machine-tool casting, actually drilling-machine sleeves the weight of which may range from 5 cwts. to 12 tons; the largest casting would measure 15 ft. in length and 30 in. in diameter, and such a casting is shown in Fig. 10.

The core is made by means of a strickle sweeping up the loam on a steel barrel. These barrels are turned by means of a machine similar to a lathe headstock. A bar in front of the operator enables rotation of the barrel to be stopped and started at will. This method enables the winding of the straw rope, and the subsequent application of the loam, to be done with considerable rapidity. The barrel is driven by means of a square shaft in which a cotter hole is provided, which is also used for keeping the core barrel from lifting when it is in the casting position in the mould. The square end of this shaft fits the standard collet of a driving head on the core turning machine. This is shown in Fig. 11. The mould is made by jarring the bottom half on a jolting machine, the top half being rammed up by a sandslinger.

Owing to the design of this type of casting, it is sometimes impossible to obtain a straight drop for the metal, and no matter where the runners are placed the metal will strike on either a shoulder of the mould or the core. Where this strike is likely to take place the mould is studded with metal studs for protection. These moulds

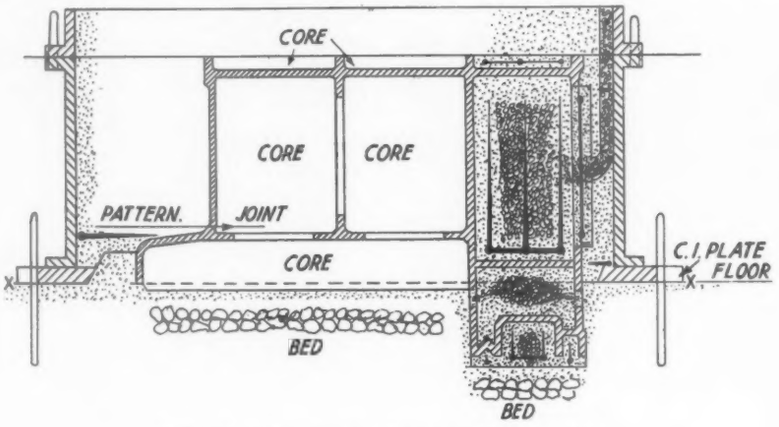

FIG. 13.—MOULD FOR GRINDING-MACHINE BED.

are always run from the top by means of pencil runners situated round the core.

No feeding takes place, sufficient head being allowed on the casting for this purpose. Bottom running for this class of work is considered dangerous, as a cleavage line may be caused by the presence of blacking or dust when the metal is rising in the mould. This can be a source of undetected weakness in the casting. When top pouring is used, the surface of the metal is being constantly agitated, and so the possibility of cleavage lines is eliminated. Fig. 12 shows the completed mould in section.

Grinding-Machine Bodies

These castings are more or less of a standard type, irrespective of the make of machine, and three standard methods can be used for moulding these castings:—One is by using a plain pattern in the foundry floor surrounded by drawbacks. This, although an expensive method of

FIG. 14.—MOULD ASSEMBLY FOR GRINDING-MACHINE BED.

moulding, does not require much tackle. The second is by means of a three-part box with two joint lines on the patterns. The initial outlay of tackle is considerable, but the whole mould is accessible and can be thoroughly dried in the foundry stove.

The third method which the author proposes to describe is achieved by using patterns with two joint lines similar to that for a three-part box but in this case the ways to joint (X, X in Fig. 13) are bedded on the foundry floor. The main body of the mould is carried in a box by means of a shaped cast-iron plate 2 in. thick

which fits round the pattern within 2 in. all round. This plate, carrying what may be termed the middle portion, is guided by means of floor stakes. A top part is used, which is located on the middle part by means of pins. The mould is dried *in situ*, and can be assembled as the cores are built up. The intricate core operations round the ways which are built up from the floor are readily accessible, which is of considerable advantage. In this case there are approximately

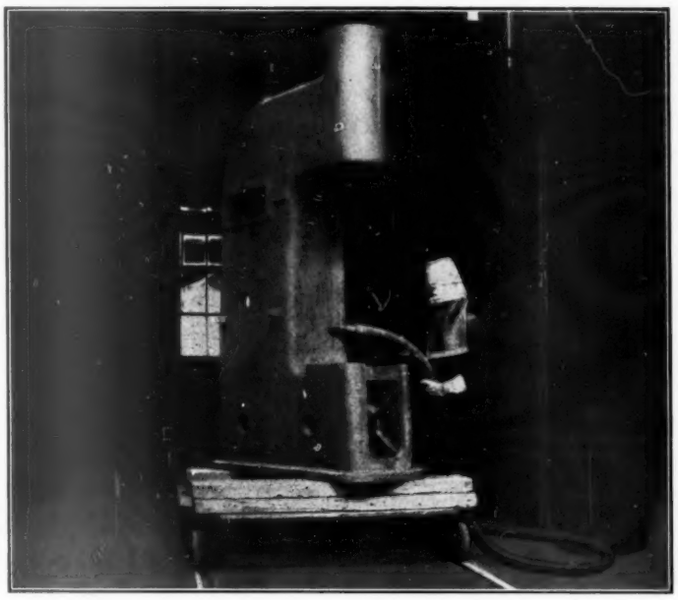

FIG. 15.—PRESS BODY BEING SAND-BLASTED.

57 cores. The metal sections are generally on the thin side. Adequate runners must be provided or some of the sections will be chilled and extremely hard to machine. Fig. 14 shows one of these moulds stripped prior to coring up.

Fettling Machine-Tool Castings

Fettling of high-duty and alloy castings presents additional problems over those manufactured from the softer irons. The iron, having a higher tensile strength, naturally requires greater manual effort to chip. Perhaps the most useful mechanical aid to fettling is the swing-frame grinder fitted with a high-speed grinding wheel. This is aided by the pneumatic hammer. Very often large heads and feeders have to be removed and these cannot always be struck off for fear of breaking in. It is usual to drill these risers transversely across the junction of the casting after which they can readily be removed. An improved finish and a subsequent aid to fine fettling on the castings can be obtained by means of a shot-blast plant.

Fig. 15 shows a casting for a 30-ton press body after being sand-blasted. This casting, on account of its thin sections coupled with high tensile strength, weighs only 34 cwt.

Design Considerations

It would not be fitting to conclude this Paper without reference to the design of castings to be manufactured from high-tensile cast iron. It is imperative that an even section be maintained throughout and that no hot-spots are created through the junction of too many ribs at one point. A transverse rib should be broken where it enters a right-angled corner by means of a small round core. A casting is not always strengthened by thickening certain sections, as a reduction of tensile strength may take place through "mass effect."

When a draughtsman designs a casting he should also visualise the moulder's parting line and incorporate the necessary taper for stripping in his design. This not only will reduce the moulding cost, but do much to eliminate misshapen castings caused through excessive rapping or uncontrolled pattern taper applied by the patternmaker.

The author wishes to apologise for the briefness of the Paper, which attempts to outline a most comprehensive and difficult type of work, any sub-heading of which offers scope for a detailed treatise. Machine-tool moulding requires constant personal supervision to detail and probably has done much to enable the small jobbing foundry to survive these days of intensive competition on account of its working owner always being on the spot with a practical knowledge of the class of machine-tool casting on which he has specialised.

In conclusion, the author wishes to thank the directors of William Asquith, Limited, and Modern Foundries, Limited, for their permission and facilities for the writing of this Paper, and to Dr. A. B. Everest, of the Mond Nickel Company, and Mr. H. F. Poole, of Keighley Laboratories, for their suggestions and help.

Optimum Blast-Furnace Capacity

In the course of a Paper on "Some Recent Developments in the Iron and Steel Industry in Britain," submitted by DR. A. MCCANCE and MR. T. W. HAND to the International Engineering Congress, at Glasgow recently, the authors, referring to blast-furnace size, pointed out that developments all over the world in this connection had been most striking during the post-war years.

While Great Britain had apparently lagged behind developments in the United States and Germany, it should be remembered that a substantial proportion of British pig-iron was made from native low-grade ores, whereby the furnace burden contained only half the iron content of the burden in the usual German or American practice. The increase in output had been obtained in the first place by increasing the size of the furnace unit, but had also been helped by the application of the latest methods of ore treatment and sizing. Some modern furnaces reached a very large size. In the United States the standard unit had become one of 1,000 tons a day, whilst the latest designs for Russian blast furnaces were based on an output of 1,500 tons per day. Power requirements for such furnaces were very large; thus a 1,000-ton furnace required 10,000 h.p., of which roughly 7,000 h.p. was needed for blowing.

(Concluded in next column.)

New Zealand Iron and Steel Industry

In March the New Zealand Parliament passed a law providing for the establishment of an iron and steel industry to be controlled and operated solely by the Dominion Government (see FOUNDRY TRADE JOURNAL, March 17, 1938). As regards the source of supply of raw materials, the new law grants to the Government control over all iron sand deposits, which total about 6,000,000 tons. Apparently the proposed works will be located at Onekaka, where a blast furnace was in operation from 1921 to 1935. Iron ore and limestone ore are found there in sufficient quantities, and manganese deposits of undetermined extent are also known to exist in the vicinity.

Production Plans

The Government proposes to manufacture steel sheets, sections, bars, wire products, rails, small billets, and foundry pig-iron. It has been estimated that the new industry will require annually some 200,000 tons of iron ore, 70,000 tons of limestone, 3,000 tons of manganese ore, 160,000 tons of coal, and 11,000 tons of phosphate rock, all of which are obtainable locally, with the exception of phosphate and, possibly, manganese. The proposed annual output of the new industry is stated to be as follows: Bars and rods, 25,000 tons; steel sections, 6,000 tons; steel sheets and plates, 24,000 tons; steel rails, 9,000 tons; wire and wire products, 19,500 tons; pig-iron, 3,000 tons; total annual output of 86,500 tons.

The Government has stated that among the benefits to be derived from the establishment of the industry is the assurance of a sufficient domestic supply of iron and steel products in time of emergency, a higher level of employment, and prospects of an expansion of the Dominion's manufacturing industries as a result of the availability of domestic iron and steel supplies and their by-products. One of the immediate incentives has been the delays experienced in securing deliveries from British and Australian iron and steel sources during the past two years.

It is anticipated that constructional operations (involving the expenditure of £NZ5,000,000) will be spread over a three-year period. The favourable report on the project prepared by the consulting engineers (H. A. Brassert & Company) was the deciding factor in the Government's decision to inaugurate an iron and steel industry.

Prospects of Success

The opinion has been expressed in New Zealand that manufacturing costs will be too high to permit the profitable operation of a plant capable of producing annually only 85,000 tons of steel products—or even 100,000 tons, which is the maximum estimated demand for the domestic product. It has also been pointed out that the estimated costs of manufacture contained in the Brassert Company's report are now antedated, and that manufacturing costs in the Dominion have risen considerably because of higher wages and freight rates and the shorter hours of labour now in force.

In recent years, practically all of New Zealand's iron and steel requirements have come from the United Kingdom and Australia, the United States accounting for only a small quantity. In 1936, the total value of New Zealand iron and steel imports was approximately £NZ2,730,269, of which the United Kingdom accounted for 69 per cent., Australia for 23 per cent, and the United States for only 1.2 per cent.

(Concluded from previous column.)

In the case of integrated works, where the steelworks depended on the use of waste gases for fuel, it was inadvisable to have fewer than three furnaces in the blast-furnace plant. Laying-off for relining, which took two or three months, would cause too great a dislocation of the production of the steelworks if the required output were concentrated in fewer units. The larger furnaces in Germany and America had on this account arisen naturally from the larger average size of the individual steelworks in those countries. In Britain the 1,000-ton per day furnace was too large, and one of approximately half that size would appear to be most appropriate to our national conditions.

Copper in Cast Iron

By A. J. NICOL SMITH, B.Sc.

(*Concluded from page 540, vol. 58.*)

SECOND PORTION OF THE INVESTIGATION

It was felt at this stage that most of the useful information had been obtained from the materials so far made, and that the information then available was sufficient to give a clear idea of the general effects of adding copper to cast iron. Further work was therefore directed to determining the influence of smaller quantities of copper on a smaller range of irons more comparable with those in general engineering use.

Addition of Copper to Cupola-Melted Irons

By the courtesy of one of the members of the B.C.I.R.A. the author was able to make additions of copper to cupola-melted metal. The metal was tapped from the cupola into 5-cwt.

TABLE VIII.—*Composition of Cupola-Melted Copper Cast Irons.*

No.	T.C. Per cent.	Si. Per cent.	Mn. Per cent.	S. Per cent.	P. Per cent.	Cr. Per cent.	Cu. Per cent.
1	3.29	1.94	1.27	0.121	0.41	0.15	0.02
2	—	—	—	—	—	—	0.24
3	—	—	—	—	—	—	0.55
4	3.25	1.99	1.28	0.128	0.41	0.16	0.58
5	—	—	—	—	—	—	0.87
6	—	—	—	—	—	—	0.96
7	3.29	1.91	1.26	0.126	0.41	0.14	1.25
8	—	—	—	—	—	—	1.41

ladles, from each of which a quantity of 1 cwt. was tapped into a handshank containing the alloying addition. From each shank so treated was cast a set of bars comprising one bar each of 0.6, 0.875, 1.2 and 2.2 in. dia., all 21 in. long. The moulds were of green-sand. The analyses of the bars are given in Table VIII, while the mechanical results are in Table IX.

Addition of Copper to Crucible-Melted Metal

A series of melts was arranged to cover the range of compositions from 2.7 to 3.5 per cent. total carbon and from 1.00 to 3.00 per cent. silicon with phosphorus contents of 0.3 and of 0.6 per cent. The metal was melted in an oil-fired crucible furnace, sufficient metal was taken into a shank to pour a set of bars of 0.6 to 1.2 in. diameter and also a fluidity test, a small wedge chill test, and a Jolley K-shrinkage test from the base metal. All the moulds were in dry-sand. One per cent. of copper was then added to the metal in the furnace and without reheating a further set of castings was made. A further 1 per cent. of copper was added to the furnace metal, making 2 per cent. in all.

TABLE IX.—*Mechanical Properties of Cupola-Melted Cast Irons.*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.				Tensile strength. Tons per sq. in.	Brinell hardness. 10/3000.	Repeated impact blows.
		2 2 in.	1.2 in.	0.875 in.	0.6 in.			
1	1,340	22.5	27.5	25.9	31.4	16.10	227	—
2	1,330	22.0	29.5	20.9F	24.3	15.42	223	—
3	1,330	21·6F	31·0	28·1	28·9	17·24	230	—
4	1,330	22.2	29.7	20.0F	21.4F	13.06F	238	2,769
5	1,340	22.6	30.6	27.8	23.6F	15.44	241	5,781
6	1,250	22.4	31.8	20.1F	24.0F	15.38	237	3,060
7	1,330	21.5	27.9	27.3	29.0	14.98	236	2,987
8	1,310	23.9	28.3	30.7	31.7	14.62	239	—

F = Flaw.

and another set of castings was poured. Finally, and still without reheating, a final 1 per cent. of copper to make 3 per cent. was added to the furnace and the final castings were poured. It was thus possible from each melt to obtain four sets of castings containing respectively 0, 1, 2 and 3 per cent. of copper. The temperature was taken at each pouring by means of a disappearing filament optical pyrometer which was frequently checked against a platinum, platinum-rhodium immersion pyrometer. It was possible to cast a fluidity test only on the first and third pourings, that is, with 0 and 2 per cent. of copper.

Throughout this series of tests the bars cast were 21 in. long. They were broken in transverse, however, on the centres laid down in the new standard B.S.I. specification; that is, the 1.2-in. bar on 18-in. centres, the 0.875-in. bar on 12-in. centres and the 0.6-in. bar on 9-in. centres. It was thus possible to obtain two results on each 0.875-in. bar and three tests on each 0.6-in. bar. The results on these bars are given as the average of the two or of the three results respectively, subject to the fact that fractures showing flaws were omitted from the averages.

The results of the mechanical tests, together with the analyses, are given in Tables X to XXV.

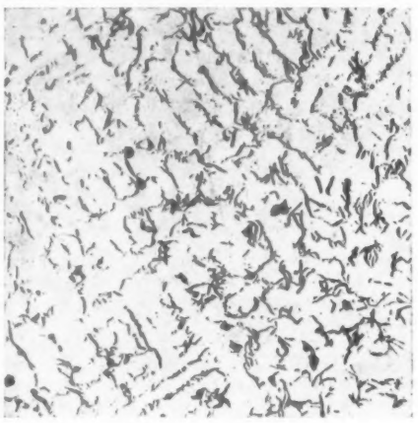

FIG. 3.—SPECIMEN A228.

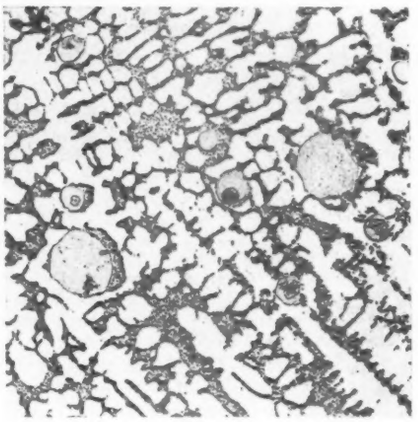

FIG. 4.—SPECIMEN A229.

Structures of 1.2-in. bars showing the effect of primary copper in causing graphite refinement. Unetched. × 50. (See the JOURNAL last week, page 538.)

In all the tests recorded in this report, the transverse results are given as transverse rupture stress or modulus of rupture, calculated by the usual formula: T.R.S. = $\frac{WL}{0.392d^3}$, where L is the distance between centres, W is the load in tons and d is the average diameter of the bar at the fracture. The hardness tests were taken on a flat ground on the side of the 1.2-in. bar close to the fracture. The tensile tests were taken on half of the 1.2-in. bar after breaking in transverse, these test-pieces being machined to 0.798 in. diameter. The repeated impact is of the Krupp-Stanton type and the specimen was taken from the centre portion of the 0.875-in. bar after the two transverse tests.

TABLE X.—*Composition of Crucible-Melted Copper Cast Irons (Set A).*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
9	2.72	1.04	1.68	3.03	0.70	0.30	Nil
10	2.71	0.55	2.16	—	—	—	0.99
11	2.70	1.15	1.55	—	—	—	1.77
12	2.70	0.72	1.98	2.93	0.66	0.29	2.44

TABLE XI.—*Mechanical Properties of Crucible-Melted Copper Cast Irons (Set A).*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.	Repeated impact blows.
		1.2 in.	0.875 in.	0.6 in.			
9	1,410	23.5F	28.0	28.5	16.80	240	1,619
10	1,420	27.8	32.9	33.8	18.14	255	2,212
11	1,430	26.3	30.3	31.0	19.08	255	2,816
12	1,340	25.6F	29.0	30.4	17.98	263	1,640

F = Flaw.

TABLE XII.—*Composition of Crucible-Melted Copper Cast Irons (Set B).*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
13	3.02	1.00	2.02	2.73	0.81	0.70	Nil
14	2.99	0.70	2.29	—		—	1.08
15	2.85	0.68	2.17	—		—	1.84
16	2.88	0.78	2.10	2.58	0.78	0.61	3.03

F = Flaw.

TABLE XIII.—*Mechanical Properties of Crucible-Melted Copper Cast Irons (Set B).*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.	Repeated impact blows.
		1.2 in.	0.875 in.	0.6 in.			
13	1,320	23.8	30.3	30.4	12.96	231	669
14	1,300	26.2	29.3	30.9	14.86	246	978
15	1,260	24.2	27.6	27.1	11.80	247	632
16	1,250	18.1F	27.7	28.4	11.82	260	280

F = Flaw.

TABLE XIV.—*Composition of Set C.*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
17	3.28	0.74	2.54	1.97	0.61	0.31	Nil
18	3.41	1.00	2.41	—	—	—	0.90
19	3.17	0.91	2.26	—	—	—	1.69
20	3.17	0.88	2.29	1.94	0.60	0.30	2.32

TABLE XV.—*Mechanical Properties of Set C.*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.	Repeated impact blows.
		1.2 in.	0.875 in.	0.6 in.			
17	1,340	26.2	30.7	31.9	16.00	208	2,346
18	1,310	25.6	31.4	31.0	15.34	214	3,760
19	1,310	25.6	29.9F	33.3	16.78	225	2,650
20	1,310	29.1	33.8	33.9	17.68	241	1,980

F = Flaw.

TABLE XVI.—*Composition of Set D.*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
21	3.25	0.85	2.40	1.98	0.45	0.59	0.08
22	3.24	0.85	2.39	—	—	—	0.70
23	3.29	0.84	2.45	—	—	—	1.35
24	3.23	0.87	2.36	1.98	0.49	0.58	1.70

TABLE XVII.—*Mechanical Properties of Set D.*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000 on 1.2 in.
		1.2 in.	0.875 in.	0.6 in.		
21	1,250	23·3	24·1	31·5	11·84	219
22	1,230	23.2	18.4F	29.7	5.90F	222
23	1,250	22.7	26.8	33.3	9.82	231
24	1,230	17.4F	15.6F	22.3	10.20	217

F = Flaw.

TABLE XVIII.—*Composition of Set E.*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
25	3.32	0.91	2.41	0.79	0.44	0.30	Nil
26	3.40	1.07	2.33	—	—	—	0.6,
27	3.35	1.10	2.25	—	—	—	1.95
28	3.27	0.99	2.28	0.76	0.40	0.29	2.65

TABLE XIX.—*Mechanical Properties of Set E.*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.	Repeated impact blows.
		1.2 in.	0.875 in.	0.6 in.			
25	1,320	25.4	35.4	—	14.42	190	831
26	1,310	26.1	30.3	33.9	14.06	209	1,734
27	1,320	27.1	28.2	33.8	14.66	229	1,810
28	1,330	29.1	26.9F	28.7	16.46	234	2,893

F = Flaw.

TABLE XX.—*Composition of Set F.*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
29	3.23	0.89	2.34	1.25	0.54	0.33	Nil
30	3.13	0.81	2.32	—	—	—	0.82
31	3.13	0.82	2.31	—	—	—	1.78
32	3.09	0.84	2.25	1.17	0.46	0.32	2.43

TABLE XXI.—*Mechanical Properties of Set F.*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.	Repeated impact blows.
		1.2 in.	0.875 in.	0.6 in.			
29	1,420	28.5	28.3	25.4	13.84	216	982
30	1,420	22.9F	23.9	33.6	12.42F	222	938
31	1,410	21.0F	28.5	29.7	16.10	236	1,449
32	1,380	24.2	30.3	26.9	15.20	232	1,699

F = Flaw.

TABLE XXII.—*Composition of Set G.*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
33	3.00	1.15	1.85	1.25	0.34	0.63	Nil
34	2.96	1.05	1.91	—	—	—	0.88
35	2.93	1.00	1.93	—	—	—	1.54
36	2.90	1.02	1.88	1.19	0.23	0.63	1.97

TABLE XXIII.—*Mechanical Properties of Set G.*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.	Repeated impact blows.
		1.2 in.	0.875 in.	0.6 in.			
33	1,360	31.1	32.0	32.8	14.10	224	1,316
34	1,370	26.3F	26.8F	30.4	14.66	227	1,612
35	1,370	25.9F	26.2F	29.8	14.78	231	925
36	1,350	17.9F	30.4	31.8	14.90	236	1,597

F = Flaw.

TABLE XXIV.—*Composition of Set H.*

No.	T.C.	C.C.	G.C.	Si.	Mn.	P.	Cu.
37	3.33	0.97	2.36	1.24	0.45	0.29	Nil
38	3.27	1.00	2.27	—	—	—	0.99
39	3.22	0.86	2.36	—	—	—	1.80
40	3.21	0.92	2.29	1.16	0.45	0.30	2.27

TABLE XXV.—*Mechanical Properties of Set H.*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.	Repeated impact blows.
		1.2 in.	0.875 in.	0.6 in.			
37	1,400	26.9	28.8	34.4	16.24	210	1,907
38	1,370	28.6	33.8	32.9	17.40	226	2,559
39	1,340	25.1F	27.6	30.8	15.96	226	1,727
40	1,320	22.4F	28.9	—	15.60F	231	1,701

F = Flaw.

Influence of Copper on Mechanical Properties

The results of the mechanical tests recorded in the Tables above confirm the results of the first part of the report, in that the influence of copper on the transverse strength of cast iron is slight, but generally favourable. The tensile strengths are usually increased to a small extent by the addition of copper, while the repeated impact value shows a marked improvement with the first 1 to 2 per cent. of copper.

Influence of Copper on Hardness

The hardness test results show a definite increase in hardness with the addition of copper. This amounts on an average to an increase of 11 points hardness for the first 1 per cent. of copper and an increase of 21 points of hardness for the first 2 per cent.

Influence of Copper on Chill

The results from the chill wedges and from examination of the test-bars, which by their variation in section constitute a chill test, show that within the range of copper content studied in this portion of the report, copper acts as a graphitising agent. A study of the chill test results shows that copper as a graphitiser is approximately one-third as powerful as silicon. This is supported to some extent by the experiments on combined additions of copper with chromium and of copper with manganese, which will be reported later.

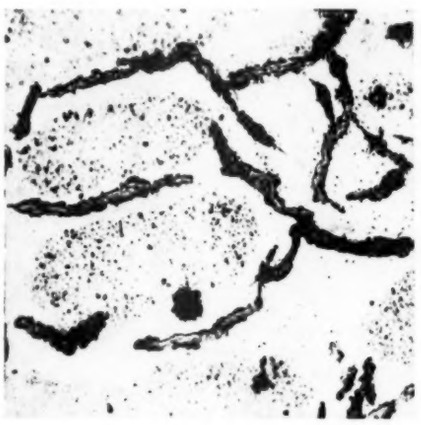

FIG. 5.—SPECIMEN A228.

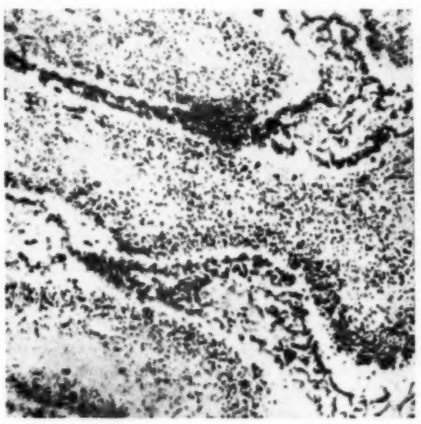

FIG. 6.—SPECIMEN A229.

Etched with 1 per cent. iodine in alcohol to show the distribution of secondary copper. × 500.

(See the JOURNAL last week, page 538.)

Influence of Copper on Fluidity

The fluidity test used was the spiral with a horn gate. In some cases the results of the fluidity tests were spoiled by differences in temperature of the metal when poured. This was the case with sets B, C and H. With the other sets, however, it was possible to obtain casting temperatures not differing by more than 10 deg. C. The results were:—

Set E.—Both fluidities of the same length.

Sets D and G.—Fluidity greater after copper addition.

Set F.—Fluidity greater before copper addition.

In the case of Set A, the fluidity was greater before the copper addition in spite of a temperature difference of 20 deg. C. in favour of the addition. These results have no exact relation to composition or to absolute casting temperature, except that the two cases D and G, where the fluidity is greater with copper, are irons of 0.6 per cent. phosphorus, while the others have 0.3 per cent. Also, the two sets A and F, which show less fluidity with copper, were cast at a comparatively high temperature.

Influence of Copper on Shrinkage

The Jolley K-test showed little variation with copper additions. A study of the whole series, however, leads to the conclusion that the first addition of copper decreases porosity, with the second addition the shrinkage is not markedly different from that shown by the base iron itself, though there is a tendency for the shrinkage to appear as a sink on the surface rather than as porosity. With the final addition of copper there is a recurrence of porosity, accompanied by sinking.

Combined Additions of Copper with other Alloys

It was shown in the first part of this Paper that combined additions of copper with manganese and of copper with chromium have a pronounced influence on the quality of cast iron. It was decided, therefore, to make some experimental melts in which a copper addition would be combined with an addition of each of the chilling elements chromium, manganese and molybdenum, in such a manner as to balance the effect on the chill. These irons were made in the same manner as the copper irons just reported.

TABLE XXVI.—*Composition of Copper-Chromium Cast Irons (Set Cu, Cr).*

No.	T.C.	C.C.	G.C.	Si.	Mn.	S.	P.	Cr.	Cu.
41	3.05	0.96	2.09	1.68	0.47	0.035	0.037	Nil	Nil
42	3.15	1.07	2.08	—	—	—	—	0.24	1.04
43	3.16	0.96	2.20	—	—	—	—	0.43	1.77
44	3.07	0.95	2.12	1.62	0.42	—	0.034	0.61	2.65

TABLE XXVII.—*Mechanical Properties of Copper-Chromium Cast Irons (Set Cu, Cr).*

No.	Transverse rupture stress. Tons per sq. in.			Tensile strength Tons per sq. in.	Brinell hardness, 10/3000.
	1.2 in.	0.875 in.	0.6 in.		
41	27.2	28.3	27.8	15.6	198
42	34.0	33.9	33.6	17.1	223
43	31.7	34.2	32.6	18.8	241
44	32.4	34.6	34.6	18.4	265

It was, unfortunately, not possible to take temperatures at the time when the bars from this melt were poured. The fluidity test shows that the metal was more fluid before the addition of alloys, but this was almost certainly due to a

temperature difference. The four chill wedges show that the first alloy addition gave a slight increase in chill depth. On the second addition the chill was the same as for the base metal, while for the third addition the chill was slightly reduced.

TABLE XXVIII.—*Composition of the Copper-Manganese Cast Irons (Set Cu, Mn).*

No.	T.C.	C.C.	G.C.	Si.	Mn.	S.	P.	Cu.
45	3.07	0.84	2.23	1.92	0.56	0.029	0.034	0.03
46	3.07	1.01	2.06	—	2.02	—	—	1.12
47	3.07	1.12	1.95	—	3.60	—	—	2.37
48	3.07	1.14	1.93	1.75	4.88	0.025	0.043	3.36

TABLE XXIX.—*Mechanical Properties of the Copper-Manganese Cast Irons (Set Cu, Mn).*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.
		1.2 in.	0.875 in.	0.6 in.		
45	1,375	23.8	26.4	25.7	14.2	205
46	1,355	26.4	26.2	31.7	16.8	237
47	1,320	27.0	33.0	30.5	17.2	293
48	1,305	25.2	24.1	17.6	15.5	347

The pouring temperatures of this series of bars were taken with a platinum—platinum-rhodium immersion thermocouple. The fluidity tests, as would be expected from the temperatures, showed that the metal was less fluid after alloy addition. The chill wedges showed a constant degree of chill, indicating that this property remained substantially constant. It will be noted, however, that the figures for the combined carbon content of the 1.2-in. bar showed a continued rise with increase in alloy content. The mechanical properties show a marked improvement with the first two alloy additions, but there is a falling off in properties other than hardness with the final alloy addition, which has led to the formation of a partially martensitic structure.

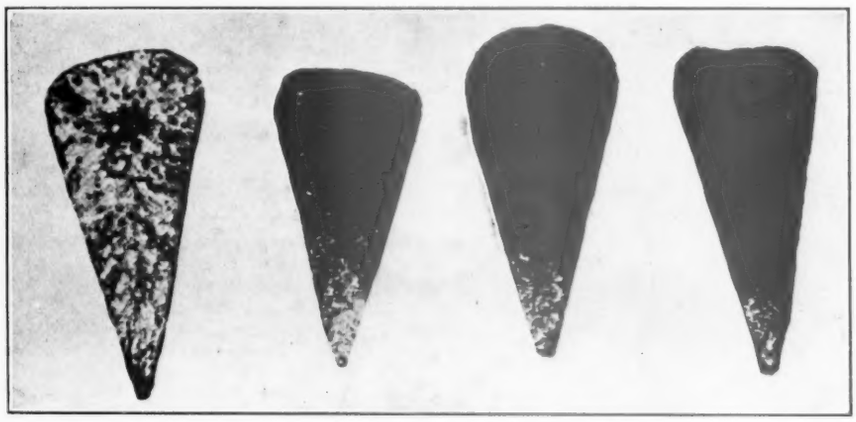

FIG. 7.—FRACTURES OF THE WEDGE TEST-PIECES FROM SERIES F (TABLES XX AND XXI) SHOWING THE INFLUENCE OF COPPER IN DECREASING CHILL. COPPER CONTENTS FROM LEFT TO RIGHT: NIL; 0.82 PER CENT.; 1.78 PER CENT., AND 2.43 PER CENT.

TABLE XXX.—*Composition of the Copper-Molybdenum Cast Irons (Set Cu, Mo).*

No.	T.C.	C.C.	G.C.	Si.	Mn.	S.	P.	Mo.	Cu.
49	3.23	1.05	2.18	1.69	0.55	0.042	0.038	Nil	0.02
50	3.10	1.10	2.00	—	—	—	—	0.96	0.77
51	3.01	1.54	1.47	—	—	—	—	1.89	1.85
52	2.78	1.60	1.18	1.54	0.49	0.036	0.031	2.85	3.18

TABLE XXXI.—*Mechanical Properties of Copper-Molybdenum Cast Irons (Set Cu, Mo).*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.			Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.
		1.2 in.	0.875 in.	0.6 in.		
49	1,280	26.6	26.8	24.5	14.4	198
50	1,240	22.3	31.1	35.8	16.4	240
51	1,260	39.5	29.0	40.3	23.0	298
52	1,240	38.3	35.5	31.9	*	409

* Test-piece not machinable.

Copper-Molybdenum Additions

The casting temperatures of this series were also taken with the immersion pyrometer. The fluidity tests show the metal is much more fluid before the alloy addition. The chill wedges show an increase in chill with increasing alloy content, indicating that the molybdenum to copper ratio was too high to keep this property constant. The first alloy addition does not give the increase in strength that would be expected from the 0.96 per cent. molybdenum present. The iron No. 51 has a tensile strength of 23 tons per sq. in. when the molybdenum content has risen to 1.89 per cent. The final metal No. 52 was martensitic in structure and unmachinable.

A further set of irons has been made by additions of copper and molybdenum to the same cupola metal used for the first series, Nos. 1 to 8. The bars were cast in green-sand moulds.

TABLE XXXII.—*Composition of Cupola-Melted Copper-Molybdenum Cast Irons (Set Cupola Cu, Mo).*

No.	T.C.	Si.	Mn.	S.	P.	Cr.	Mo.	Cu.
7	3.29	1.91	1.26	0.126	0.41	0.14	Nil	1.25
53	3.02	1.76	1.12	—	0.40	0.14	0.22	1.32
54	3.03	1.76	1.06	—	0.40	0.15	0.40	1.05
55	3.05	1.76	1.04	—	0.39	0.14	0.68	1.31

TABLE XXXIII.—*Mechanical Properties of the Irons Shown in Table XXXII (Set Cupola Cu, Mo).*

No.	Casting temp. Deg. C.	Transverse rupture stress. Tons per sq. in.				Tensile strength. Tons per sq. in.	Brinell hardness, 10/3000.
		2.2 in.	1.2 in.	0.875 in.	0.6 in.		
7	1,330	21.5	27.9	27.3	29.0	14.98	236
53	1,330	21.2F	31.2F	31.1F	19.5F	15.70	237
54	1,330	28.5	33.7	26.4F	31.5	17.28	255
55	1,330	26.6F	33.9	36.2	39.2	18.40	264

F = Flaw in fracture.

These results show, of course, the effect of increasing molybdenum content on a material of approximately constant copper content. They show that good strength results can be obtained by the addition and indicate that the simultaneous use of copper would enable molybdenum additions to be used without influencing the chilling properties of an existing foundry mixture.

The combined addition of copper with one of the chilling elements gives an easy method by which a foundry can make alloy additions to an ordinary good class iron without appreciably altering its casting characteristics and without being put to the necessity of adjusting the cupola charge to maintain a constant chill. Combined additions of copper and manganese give a rather large bulk of addition which, however, dissolves with surprising ease in fairly hot metal. The resulting alloy shows an increase in strength and hardness compared with the original metal; especially is this the case in respect of the hardness if sufficient alloy is added to bring the material towards the martensitic structure which is so hard as generally to be considered unmachinable.

The combined addition of copper and chromium is less in bulk than the copper + manganese addition, since chromium is a more powerful chilling agent than manganese. The addition is quite readily made, providing that the ferro-chromium is finely crushed. For a given copper content or for a given tensile increase, this addition is cheaper than the copper + manganese addition. It gives rise to increase in strength and hardness, the strength increase being of the same order as in the copper + manganese addition (comparison being made on the basis of the copper contents) while for the same strength increase the hardness rise is less pronounced, although still considerable. The mechanical properties of these irons are very good and there is no doubt that a combined addition of copper and chromium constitutes an effective and comparatively cheap method of improving the strength and hardness of cast iron.

Microstructure of the 1.2-in. Bars

The microstructures of the irons mentioned in this section of the Paper show that, so far as copper alone is concerned, there is no effect on the microstructure beyond a refining action on the pearlite of the iron and to some slight extent on the graphite size. It was mentioned earlier in the Paper that no new constituent is introduced into the structure by copper, until the secondary copper begins to separate at 3.5 per cent. copper. The irons in this portion of the Paper do not exceed that figure.

The copper-chromium series show a definite refining of pearlite and graphite with increasing alloy content, and in the final bar of the series, No. 44, there is a little eutectic carbide present in the very broken fan shapes reminiscent of the appearance of chromium carbide in austenitic irons. The copper-manganese series show a refinement of pearlite following the first alloy addition. The second alloy addition gives an almost emulsified pearlite with areas, about 20 per cent. of the total, consisting of martensite. There are also present some massive carbides in occasional lumps. The final alloy addition of this series (Bar No. 48) contains a little more massive carbide in a mixed matrix consisting of about equal parts of very fine pearlite and martensite. The martensite in this bar is more acicular in type and finer than in the previous bar (No. 47), where the needles showed a tendency to have rounded edges.

The copper-molybdenum series (Irons 49-52) show that the first addition refines the pearlite and also produces some areas of ferrite containing rounded particles of carbide. As has been noted before in molybdenum irons, an increase in alloy content causes these areas to increase at the expense of the pearlite, while at the same time the carbide inclusions become more acicular. The third bar, No. 481, of this series consists almost entirely of this structure and also contains a little eutectic carbide of the fine fan-shaped type. The final bar of this series would be classed as definitely martensitic and the carbide particles are more numerous.

CONCLUSIONS

(1) Under normal casting conditions, the liquid solubility of copper in grey cast iron is about 5.5 per cent. Beyond this percentage, visible globules of primary copper are present. The equilibrium solid solubility has not been determined, but under normal casting conditions grey iron is capable of dissolving 3.5 per cent. of copper without the appearance of free copper in the microstructure. Above this percentage the free copper is present as dispersed microscopic particles termed secondary copper. These solubility limits are little affected by rate of cooling

or by composition, except that the presence of nickel increases the solubility. In quantities less than 3.5 per cent. copper in grey cast iron behaves as if in solution, and this solution is comparatively stable to heat-treatment.

(2) In quantities up to 3.5 per cent. copper acts as a graphitising agent, being about one-third as powerful as silicon. Further copper beyond this figure reverses the effect and causes increase in chill, the effect being apparently due to dilution. No tendency to decompose the carbide of pearlite has been noticed.

(3) The hardness of grey cast iron is increased by copper dissolving in the matrix, although since copper acts as a graphitising agent it may simultaneously reduce the hardness by causing the decomposition of free cementite. In the absence of graphitising effect the hardness increase is about 10 to 11 points Brinell for each 1 per cent. of copper.

(4) The influence of copper on the transverse strength is only slight, but is favourable. The influence on the tensile strength is more markedly favourable than is the case with the transverse strength. The resistance of grey cast iron to impact shows improvement with the first 1 to 2 per cent. of copper. In general, the mechanical properties reach their optimum values between 1 and 2 per cent. of copper.

(5) Precipitation hardening of pearlitic grey cast iron gives no results of practical importance

(6) Copper has little influence on the microstructure of cast iron. It causes refinement of the pearlite and of the graphite. Free cementite is decomposed, but no new constituent is introduced into the structure until free copper appears at 3.5 per cent. Copper in excess of the liquid solubility limits is capable of giving rise to supercooled graphite.

(7) Copper in quantities up to 1 per cent. improves grey cast iron from the point of view of shrinkage. With 2 per cent. copper the shrinkage is about the same as in the base metal, while with 3 per cent. the material becomes definitely worse from this point of view.

(8) The combined addition of copper together with one of the chilling elements manganese, chromium or molybdenum, results in improved hardness and strength. Copper with manganese gives a marked hardness increase, copper with chromium gives an all-round improvement, while an addition of copper + molybdenum allows molybdenum to be added to an existing foundry mixture without influencing the chilling properties. Additions of copper + manganese or copper + molybdenum are capable of giving a martensitic structure.

Comparison with other Recent Work

Since this investigation began there have been several contributions to the literature of copper in cast iron. Of these, perhaps the most important is the Paper by Eastwood, Bousu and Eddy" on "Copper and Copper-Manganese Grey Cast Iron." It seems worth while making a comparison of this report with the finding of the present investigation.

(1) *Solubility and Hardness.*—The American report gives no direct consideration to solubility beyond a note that copper is effective in increasing hardness up to 5.5 per cent., though the rate of hardness increase is less after 3.0 to 3.5 per cent. copper is exceeded.

(2) *Chill.*—It is found by Eastwood, Bousu and Eddy that copper has no influence on the chill of irons containing more than 2.0 per cent. silicon, though there is a very slight tendency to increase the chill of these irons when the copper exceeds 3.0 per cent. With a silicon content of about 1.75 per cent., copper up to 3.0 per cent. reduces chill slightly, after which more copper increases the chill. With a silicon content of 1.25 to 1.50 per cent., copper up to 4.0 per cent. reduces chill markedly, though when the copper exceeds 4.0 per cent., there is a slight increase in chill.

A study of the irons reported in this Paper, with these findings in mind, has not shown any confirmation of this effect of silicon. The reversal of chill noted by both Papers had apparently not previously been published except for a reference by Taniguchi.

(3) *Mechanical Properties.*—The American Paper differs from this present Paper in finding a slight adverse effect of copper on transverse strength, though both are agreed on the influence on the tensile strength.

(4) *Combined Additions.*—Both reports emphasise the good results to be obtained from combined copper and manganese additions, while this report also deals with copper-chromium irons.

This short comparison has noted only the main differences or important similarities between the two reports. In many points of detail they are in agreement. It is probable that many of the points of difference can be attributed to the differences in the tests used and in their interpretation. This, for example, is likely to be the case with the chill tests.

Institute of British Foundrymen

ELECTION OF NEW MEMBERS

At a Council meeting of the Institute of British Foundrymen, at the Technical College, Bradford, last month, the following were elected to the various grades of membership.

As Members.

J. Baggott, senior Inspector-General of Works, Public Works Department, Iringa, Tanganyika; D. Cameron, pig-iron salesman, Leigh & Sillavan, Limited, Manchester; J. V. Collier, managing director, Northampton Foundry Company, Limited, Balfour Road, Northampton; W. H. Crawshaw, representative, Morgan Crucible Company, Limited; J. Fairclough, director, Warrington Light Castings Company, Limited; F. G. Harris, managing director, Atlas Malleable & General Ironworks, Limited, Walsall; A. Hill, metallurgist, Canada Iron Foundries, Limited, Three Rivers, Prov. Quebec; G. W. Littlewood, foundry manager, Sandwell Casting Company (Sanbra, Limited), West Bromwich; W. Meredith, foreman moulder, Hadfields, Limited, Sheffield; E. A. Phillips, managing director, Harper, Phillips & Company, Limited, Grimsby; C. Pullen, sales manager, Sir W. G. Armstrong, Whitworth & Company, Limited; A. J. Stokes, chief metallurgist, Sheepbridge Stokes Centrifugal Castings Company, Limited, Chesterfield; C. H. Tanner, director, District Chemical Company, Limited, London; W. Taylor, foundry engineer, J. Evans & Company, Manchester; F. Wade, general manager, R. J. Hunt & Son, Limited, Birmingham; R. White, works manager, Atlas Malleable & General Ironworks, Limited, Walsall, and F. J. Williams, assistant foundries manager, Vickers-Armstrongs, Limited, Barrow-in-Furness.

As Associate Members.

J. F. Barnes, foreman coremaker, Ruston & Hornsby, Limited, Lincoln; J. R. Booth, foundry assistant, Booth & Brookes, Limited, Burnham-on-Crouch; H. E. Comins, metallurgist, Ruston & Hornsby, Limited, Lincoln; C. H. Enders, instructor of patternmaking, Walthamstow Technical College, London; F. E. Ironmonger, foundry foreman, Ruston & Hornsby, Limited, Lincoln; H. H. Launder, assistant foreman moulder, Ruston & Hornsby, Limited; W. Long, assistant foreman, Ruston & Hornsby, Limited; T. W. Marshall, patternmaker, Austin Motor Company, Longbridge; T. H. North, castings inspector, Ruston & Hornsby, Limited; H. Preston, foreman patternmaker, Dean, Smith & Grace, Limited, Keighley; R. L. Simpson, assistant foundry manager, Modern Foundries, Limited, Halifax; L. Taylor, moulder, Newton & Company, Manchester; A. T. Tod, foreman patternmaker, Rowe Jewell & Company, Limited, Johannesburg; G. L. Wilde, assistant to foundry manager, Walmsleys (Bury), Limited, Bury, and J. Worthington, assistant works manager, Izons & Company, Limited, West Bromwich.

Company Meetings

Stanton Ironworks Company, Limited

MR. CHARLES R. CROMPTON, presiding at the annual meeting of the Stanton Ironworks Company, Limited, held at Derby on Monday, June 27, said that the profit for the year constituted a record. A year ago they were blowing seven out of their nine blast furnaces at Stanton and Holwell, and while during the past year their full complement of nine had been in blast, recently they had, unfortunately, to shut down three, leaving only six at work, and even these six during recent months had been working on slack blast. The two furnaces at their Wellingboro' works remained in operation, but were also working on slack blast. They were refraining from increasing their stock of iron at to-day's cost of production, and no doubt others were doing likewise. They had in stock a year or two ago some 140,000 tons of iron which had been made under economic conditions, and was subsequently turned to good account. To-day they were relieved to know that their stocks did not exceed some 15,000/20,000 tons, and they could not allow this total to be exceeded unless the price of coke was reduced. He mentioned last year that they were giving careful consideration to the installation at Stanton of a battery of coke ovens for purposes of placing the company in a position of greater independence for this important section of their raw material requirements. They were now proceeding with the erection of a battery of ovens which would give about 3,500 tons of coke per week, and had made provision, in the event of necessity, for doubling this battery. A pig-iron casting plant at their Holwell furnaces had been satisfactorily set to work, and the resulting product, free as it was from sand, was being favourably received by the foundries. Last year he reported that they had put down a special plant at Stanton consisting of six machines, with two machines as spare, for the production of centrifugal pipe of 3 in. diameter, in lengths of four metres (13 ft. 1½ in.). One of their objects was to produce more effectively one size of pipe in a works specially laid out for the purpose, and another was to relieve the strain on their original spun pipe plant at Stanton, which consisted of twenty machines for making pipes from 3 in. dia. up to 20 in. dia., in lengths of 12 ft. and 18 ft. The new plant had operated satisfactorily during the past year, and the original plant had, generally speaking, been kept fully employed on other sizes. Encouraged by the results obtained, they had put down a further new plant for the production of pipes of 4 in. dia., in lengths of 12 ft. and 18 ft., consisting of eight machines, with two spares. This had recently been put into production, and will be confined to the mass production of that one size of pipe. The licence which they acquired from Cochranes (Middlesbro') Foundry, Limited, for the Mairy process had fully justified the claims originally made. Their general foundries were well supplied with work at the present time, and tunnel segments had continued to give them some very useful orders.

Allied Ironfounders, Limited

The annual meeting of Allied Ironfounders, Limited, was held in London on June 28. MR. ALEXANDER WILLIAM STEVEN (chairman), reviewing the general trading conditions during the year, said their experience ran parallel to that of many other industrial companies. The first quarter ending June, 1937, showed great activity both in demand and in output. During the summer pressure on their works relaxed and for the remainder of the year the volume of orders fell considerably below that which ruled in the corresponding period of the previous year. Again like many other manufacturing companies, prices of all their raw materials were sharply advanced. These high prices still persisted. Wages and working conditions of their employees had been substantially improved. In May, 1937, a general increase in wages of 4s. per week was granted. Improvements in the physical conditions and environment within the works had been effected, and recently, by agreement with the trade unions, payment for holidays had been established as a general rule of the whole industry. Provision had been made in this year's accounts for payment for holidays covering five months. On a whole year the cost of this concession was equivalent to 1 per cent. on the ordinary share capital of the company. They must be prepared for a considerable falling off in building operations. Nevertheless, there seemed to be many reasons for believing that they need not anticipate a serious or immediate slump.

Sand-Blasting as Applied to the Vitreous Enamelling Process*

By H. WHITAKER, M.Sc.

Sand-blasting is a process whereby grains of abrasive are thrown forcibly against the articles to be cleaned or treated. "Blasting" would be a better general term to describe the process, as nowadays sand is very little used, in this country, at any rate. The abrasive, generally crushed iron grit, is impelled against the articles being treated either by a stream of compressed air or from the blades of a wheel, rotating at high speed.

History

The original patents are said to have been taken out by Tilghman in 1870, when the process was used for obscuring glass. It was first applied to the metal trades in this country in Sheffield and Derby, about 1896, when it was used for cleaning castings, sand being the abrasive used. It was carried out in the open air, no precautions being taken regarding dust. About the year 1900, attempts were made to confine the process to an enclosed chamber, and crushed iron grit was introduced as the abrasive.

Object of Blasting

The object of blasting prior to vitreous enamelling is threefold:—(1) To remove the hard "skin," which is of a different nature from the rest of the metal and does not enamel well; (2) to remove all surface impurities, such as sand, blacking and the oxide formed during annealing; and (3) to roughen the surface and thereby cause a "bond" which enables the enamel to grip the metal. For cast iron no other method of cleaning has been found so effective, and it may also be applied to the heavier gauges of sheet steel.

It is vitally important that the blasting be done thoroughly and efficiently, because very many enamelling troubles can be traced to faulty blasting; for example, lack of care on the part of the operator, or the presence of oil or water in the compressed air.

Choice of Plant

When the prospective purchaser of blasting plant knows the type of goods he is to handle, and the quantity per hour, the suppliers have little difficulty in advising as to the best type to instal. When, however, the user himself—an enameller working for the trade, say—has not this exact knowledge (as the work may vary from a knob weighing an ounce to a heavy pan weighing up to a ton), then the choice of plant requires careful consideration.

Assuming the class of work to be known, the type of plant is largely settled by the output required; for example, on light castings (stove grates, etc.) the different types would turn out approximately:—Cabinet, 1 cwt.; room, 2 cwts.; and rotary table, 6 to 8 cwts. per hour per man (operator only). It is best to select blasting equipment on the cost per unit cleaned, because low running costs can easily outweigh an apparently high capital expenditure. Assuming a daily output of 25 tons, a saving of £100 in purchase price can be wiped out in two months if the operating costs are 2s. per ton higher than they might be. Moreover, after that there would be a loss of £100 every two months.

OUTPUT OF PLANT

This depends on (*a*) air pressure employed; (*b*) air capacity; (*c*) bore and type of nozzle; (*d*) nature of abrasive; and (*e*) type of plant.

(a) Air Pressure

Difference of opinion still exists as to the best pressure for vitreous enamelling. A pressure of 50 to 55 lbs. per sq. in. at the nozzle appears to be generally used in this country, although this may rise to 70 to 80 lbs. or fall as low as 30 to 35 lbs. Probably the last range is the absolute minimum for giving a satisfactory bond for the enamel, and the higher pressures are used with the object of obtaining a greater output. It should be borne in mind, however, that the power required to compress air increases rapidly with the pressure; for example, to produce 100 cub. ft. free air per minute at 30 lbs. pressure, 12 h.p. are required, whilst for the same amount at 60 lbs. pressure 18 h.p. are required. Few users of compressed air have an accurate idea of what it costs. It has been estimated that a plant with three $\frac{1}{4}$ in. nozzles costs about 2s. 6d. per hr. for compressed air, or over £300 per year.

MR. H. WHITAKER.

(b) Air Capacity

The air consumption depends solely on the pressure and the bore of nozzle, and as the latter increases through wear, the compressor should be well on top of its work, say 20 per cent. above the demand of a new nozzle. To obviate stoppages due to breakdowns, repairs, etc., it is better to have two or more medium-sized compressors than one large one.

(c) Bore and Type of Nozzle

The wear of nozzles should be carefully controlled. A $\frac{7}{16}$-in. bore nozzle will absorb 205 cub. ft. free air per minute to operate it at 60 lbs. pressure, but when the jet is worn to $\frac{1}{2}$-in. bore 270 cub. ft. are used at the same pressure, *i.e.*, an increase of over 30 per cent. Nozzles of bore varying from $\frac{5}{16}$ to $\frac{7}{16}$ in. are generally used for vitreous enamelling, the most usual being $\frac{3}{8}$ in. They are usually made of chilled cast iron and last 6 to 8 hours. The use of "long-life" nozzles made of special alloys such as boron-carbide or tungsten-carbide is steadily increasing. They have a life of from 1,000 to 2,000 hrs. with careful use. The saving in their use is due not only to the bore remaining practically constant, but also to the time saved through not having to change them so frequently. It is necessary to keep a control on the nozzle-holder washers, as if these be allowed to wear too much, the outer cover of the nozzle becomes damaged beyond repair.

(d) Nature of Abrasive

In this country the use of crushed chilled white iron grit is now practically universal, because of the following reasons:—

(1) The risk of silicosis is greatly reduced.
(2) Although more expensive in first cost, it has from 10 to 20 times the life of silica.
(3) It is estimated that 1 ton of iron grit will do the work of 16 tons of silica.
(4) Very much less dust is formed, which reduces the problem of its disposal.
(5) Nozzles last longer with iron grit than with quartz.

Claims have been made that silica is better for certain purposes, *e.g.*, for acid-resisting enamels, but these seem difficult to substantiate. In the case of hollow articles where there is a possibility of some abrasive being left inside, there might be some advantage in using silica. The chemical composition of crushed iron grit of British manufacture is approximately as follows:—C.C, 3.1; Gr, nil; Si, 1.8; Mn, 0.4; S, 0.1; P, 1.1; Cr, 0.15 per cent. The Firth-Diamond hardness of such grit varies between 750 and 880. Hardness, however, is not the only desirable quality, and the manufacturers, by keeping the production under close technical control, can strike a balance between hardness and "toughness."

(e) Type of Plant

There are five types of plant in common use: (1) room; (2) cabinet; (3) rotary table; (4) barrel; (5) airless type, and their respective (A) advantages and (B) disadvantages are as follow:—

(1) *Room*:—

(A) The "universal" unit, as it will take any size of casting. It has greater flexibility of operation than the cabinet.

(B) High initial cost; excavation necessary; occupies large floor space; requires large dust equipment, and operator must be inside room.

(2) *Cabinet*:—

(A) Operator can work outside; small initial cost and floor space, also exhaust equipment.

(B) Smaller output, due to restricted manipulation of nozzle and vision of work. It cannot handle large castings.

* Paper presented on behalf of The Institute of Vitreous Enamellers to the Annual Conference of the Institute of British Foundrymen in Bradford.

(3) *Rotary Table*:—

(A) High output; will handle wide variety of flat castings, both large and small. The operator can work outside; no excavation is required, and it takes less floor space than room.

(B) Practically constant maintenance required. One type is only suitable for flat work, therefore another kind of plant is necessary (*e.g.*, cabinet) to look after edges. In another type, however, edges up to 1 in. are being satisfactorily cleaned. Requires large compressor as several nozzles are operating simultaneously.

(4) *Tumbling Barrel*:—

(A) Very economical, simple and robust. Operator can work outside.

(B) Only suitable for fairly small work, which can be tumbled without risk of breakage. As very few enamelling plants have sufficient work of this kind to keep the barrel running to capacity, this type is not often installed.

(5) *Airless Type*:—

(A) No compressed air is required, therefore cost of motor, compressor, receiver, piping, etc., is saved; also no trouble due to oil and water in air. No excavation; small floor space; lower power costs, compared with room or rotary table; no rusting of abrasive; the operator can work outside, and the work is more thoroughly cleaned than in any other type.

(B) Initial cost relatively high, also cost of maintenance.

In addition to its application to the barrel type, airless blasting is now being applied to the rotary table, with satisfactory results. By adjusting the angle of blast, vertical surfaces or edges can be cleaned. The airless type will clean four times the area cleaned by the pressure type in the same time, with an expenditure of one-tenth the horsepower. The chief reason for its high output is the large amount of grit which is flung on the work, being eight or nine times as much as in the pressure type, in the same time. It may be difficult to compare the actual velocity of the grit as it strikes the work, in the two types, but the cutting action in the airless type is at least equal to that obtained at 60 lbs. pressure in the pressure type. An average load of 3 to 4 cwts. of light castings is satisfactorily cleaned for vitreous enamelling in about 15 min., in the "Tumblast" machine. It should be made clear that the airless-type is not suitable for every class of work, but for work for which it is suitable it shows advantages both as regards quality and cost over any other type of which the author has had experience.

Operating Troubles

The chief troubles in the pressure type are due to water and oil in the compressed air supply.

Water.—It has been estimated that with a $\frac{3}{8}$-in. nozzle operating at 80 lbs. pressure, the amount of moisture carried in with the air per hr. is about $\frac{3}{4}$ gall. The air is heated while being compressed, which enables it to carry more water in the form of vapour. If moisture travels as far as the pressure chamber before condensing, it causes the abrasive to congeal and results in the apparatus becoming "clogged," also it is driven into the castings and causes rusting if they are allowed to stand. To prevent this trouble inter-coolers and after-coolers are employed, to cool the air and cause condensation near the compressor. Main pipe-lines should have a slight fall, with drain taps at the ends of the lines. All branch connections should be taken from the top of the main line, and it is advisable to fit a centrifugal type of separator immediately before the pressure unit. In some cases it is found advantageous to heat the air just before it enters the apparatus, generally by a gas jet, in order to vaporise any remaining traces of moisture. To keep down the temperature it is advisable to use a two-stage compressor, at any rate for the higher pressures.

Oil.—As this does not vaporise so readily as water it is not generally present to such a great extent, but if it gets through to the castings it causes far more trouble than water, because the enamel "crawls" and will not adhere. The compressor makers have introduced several modifications to overcome this trouble. The compressor should be double-acting, so arranged that a point on the piston rod does not enter both cylinder gland and crank chamber gland, thereby preventing the oil being carried forward. There should be an air gap between cylinder and crank case. Slightly tapered pistons and forced-feed lubrication (in place of the old splash method) have also assisted in this direction. The auxiliary oil feed to the top of the piston should be kept to an absolute minimum, 3 drops per min. for 1,000 cub. ft. air being ample. Oil can be removed from the main pipe-line by the use of cocoa-mat filters.

Silicosis

This disease is contracted through penetration to the lungs of dusts containing silica. To damage the lungs, the particles must be less than $\frac{1}{150}$ mm. in diameter, in other words they are invisible to the naked eye, and they must be inhaled over a considerable period. Although the almost universal use of iron grit has very greatly reduced the silicosis risk, it is still present, and it is difficult to convince sand-blast operators that it is the invisible particles which cause the trouble.

It has been calculated that there may be up to 3,000 million such particles per cub. ft. of air in a sand-blast room, and the risk of silicosis exists with anything above, say, 10 million. To guard against this, the most stringent care should be taken that helmets and protective clothing be kept in good condition and not left lying about when not in use. Also exhaust systems should be kept in perfect order, and leakages stopped. Workers in the vicinity, apart from the operators, should realise that they are not immune from danger, and should take precautions accordingly.

Further Developments

As a user of blasting plant, the writer respectfully suggests a few directions in which the manufacturers might improve their service to the enamelling industry:—

(1) *Pressure Plants.*—Pressure apparatus should be made more accessible, so that stoppages due to damp shot, etc., can be more quickly rectified. It should also be stronger and more robust, to withstand the rough usage to which it is subjected.

(2) *Airless Plants.*—There are certain parts which vitally affect the performance of the apparatus and research should be carried out with a view to giving longer life to these components, *e.g.*, by making them of special alloys.

(3) *Iron Grit.*—Research might be carried out using varying air pressures and grades of grit, with a view to utilisation of some of the grades not at present in common use for enamelling. A test should be evolved (*e.g.*, microscopic, or connected with "pick-up" of enamel) to ascertain the degree of "pitting" best suited to take enamel.

In conclusion, the writer wishes to express his indebtedness to the various suppliers of blasting equipment, who have given willing assistance in the compilation of this short Paper.

The Institute of Vitreous Enamellers

THIRD SCOTTISH REGIONAL CONFERENCE

For the third year in succession, a regional conference of the Institute of Vitreous Enamellers was held in Glasgow during Whitsuntide week-end. This year, because of the incidence of the British Empire Exhibition, meetings were held in the Congress Hall at Bellahouston Park. The conference was organised by Mr. J. G. Roberts, of Shanks & Company, Limited, of Barrhead, and was presided over by Mr. W. H. Whittle, the chairman of the Institute.

A welcome was given to the members by MR. L. KER ROBERTSON, representing the Exhibition Council of Management, who took the opportunity to give a *résumé* of the activities represented at the Exhibition.

MR. W. H. WHITTLE, after thanking Mr. Ker Robertson for his address, made reference to the serious loss the Institute had sustained through the death of its first President, Dr. Mellor. He recalled with pleasure the previous meetings held in Scotland, and apologised for the small number of visitors from the South; this was no doubt due to the calls made on their time by other conferences and to the forthcoming visit to America. The Institute was consolidating the progress made since its inception four years ago, and he appealed to those members of the industry not yet associated with the Institute to interest themselves in its work. Only by added support, he said, could the Institute carry through its proposed programme.

The Council had at last appointed a research officer—Dr. Martin—and his work would supplement the interesting lectures which had been delivered in the various centres. Dr. Martin would assume his duties on July 1. He was well known as a scientist, and he would be taught at an early stage the technique of vitreous enamelling. This appointment had been made in conjunction with the British Cast Iron Research Association. With this appointment came several advantages. In the first place, the Institute would have recourse to the Association's library, which, so far as cast iron was concerned, was equal to any in the world. Then there would be an abstracting service from foreign sources of technical literature; thus, the research work of the world would become available. A final advantage was that there would become available a centralised establishment where members could send samples of various materials for analysis, where they could be sure that the charge would be reasonable and the results comparable throughout the industry. This obviously was a great forward step for such a young Institute to take, and the Council were relying on increased support from the industry, which up to now it had served so well.

In conclusion, Mr. Whittle expressed the view that the trade outlook was distinctly promising, as the scope for vitreous enamelling was unlimited, providing always that a high standard of quality was maintained. He then asked Dr. James White to present his Paper on "Oxidation and Adhesion." This is printed elsewhere in this issue.

A vote of thanks to the author for his Paper was proposed by MR. W. S. GRAINGER and seconded by the CHAIRMAN.

The second day of the Conference, Whit Sunday, was spent touring the Highlands by motor coach, whilst on Whit Monday the members were addressed by the Chief Factory Inspector in the Glasgow district on the new Factories Act and its implications, and by the Chief Medical Inspector in the Glasgow district on the medical aspects of the Factories Act affecting enamelling works.

During the Conference the members had ample opportunity of making a tour of the Exhibition.

Oxidation and Adhesion*

By JAMES WHITE, B.Sc., Ph.D., A.R.T.C.

For a complete understanding of many high-temperature processes a knowledge of the relationships between the oxides of iron is necessary. Several investigations in recent years have shown that the enamelling of iron and steel is such a process. During the firing of the enamel layers on the metal the atmosphere is normally oxidising throughout, and hence oxidation of the metal surface is to be expected. This is particularly the case during the period before fusion of the ground-coat takes place, for access of oxygen to the metal is but little inhibited by the porous layer of dried enamel. Even after fusion of the enamel, however, there is reason to believe that the supply of oxygen to the metal is not entirely cut off, for diffusion of oxygen through the fused enamel glass seems possible. Several workers have drawn attention to this aspect of enamelling, and a theory of adhesion has even been advanced which depends on oxidation of the underlying metal surface taking place after the enamel has fused. A knowledge of the high-temperature chemistry of the oxides of iron is, therefore, of some importance to enamellers.

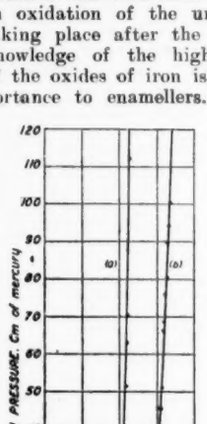

FIG. 1.—DISSOCIATION PRESSURE CURVES OF FERRIC OXIDE. (*a*) INITIAL DISSOCIATION PRESSURE OF Fe_2O_3. (*b*) DISSOCIATION PRESSURE OF SATURATED SOLUTION OF Fe_3O_4 IN Fe_2O_3.

The System Iron-Oxygen at High Temperatures

In studying the relationships between the oxides of iron at high temperatures the thermal equilibrium diagram of the system iron-oxygen makes a convenient starting-off point. Some time ago in a Paper on adhesion Kautz[1] drew attention to the importance of this system to enamellers. Several forms of the diagram have been proposed by different investigators, these differing mainly as regards the saturation limits of solid solution ranges, and (particularly in the region between the compositions FeO and Fe_3O_4) in the temperatures of melting. The diagram suggested by Matthewson, Spire and Milligan,[2] as regards its main outlines at least, has gained fairly wide acceptance.

It will suffice to indicate the principal features of the diagram briefly in tabular form.

(*a*) Oxygen has appreciable solubility in both liquid and solid iron. Below the melting point it is usually accepted that the solubility is of the order of 0.05 per cent. oxygen, being slightly higher in γ-iron than in the other forms. In the liquid state at the melting point, the solubility is given as 0.21 per cent., while at 1,600 deg. C. it is 0.30 per cent. For higher oxygen contents than this in the liquid state, two immiscible liquid phases appear.

(*b*) Ferrous oxide melts incongruently at 1,370 deg. C., undergoing dissociation with liberation of metallic iron saturated with oxygen, which phase is not completely dissolved till a temperature of over 1,400 deg. C. has been reached. Ferrous oxide is also unstable below 570 deg. C. On cooling below this temperature, it dissociates into Fe_3O_4 and oxygen-saturated iron. This is a sluggish reaction, however, for Chaudron and Forestier[3] got only 55 per cent. dissociation occurring at 445 deg. C. in 24 hours. Hence ferrous oxide can be got at room temperatures by cooling it quickly from above 570 deg. C. The reverse change, *i.e.*, the reaction between oxygen-saturated iron and Fe_3O_4 above 570 deg. C., is also a sluggish one.

(*c*) The solubility curve of iron in ferrous oxide between 570 deg. and 1,370 deg. C. lies, according to these authors, entirely to the right of the composition FeO. Hence, strictly speaking, the compound FeO does not exist in the solid state, and the name Wustite has been applied to this phase to avoid confusion. This conclusion has not passed unchallenged, but it is supported by the results of iron-oxide reduction experiments[4] and X-ray investigations[5].

(*d*) There is a eutectic between Wustite and Fe_3O_4 melting at approximately 1,170 deg. C. There is also a marked solubility of oxygen in Wustite.

(*e*) There is considerable solid solubility of Fe_2O_3 and Fe_3O_4 in one another at high temperatures, and there is a peritectic reaction involving the two solid solutions at the melting point.

An important application of the knowledge summarised in this diagram is to the formation of scale on iron on heating in air or oxygen. According to the diagram, below the temperature of 570 deg. C. FeO will not be formed on the surface of iron exposed to oxygen, Fe_3O_4 being the stable oxide of iron in contact with the metal under these conditions. Hence, on heating iron articles progressively from room temperatures, the first thin scale will consist of Fe_3O_4, as no FeO can form till the temperature is in excess of 570 deg. C. Above 570 deg. C. FeO will begin to form next to the metal; but, in actual fact, in the case of thin scales such as are met with during enamelling, the FeO zone remains very thin, such are the relative rates at which it is oxidised by oxygen diffusing through the scale, and at which it forms on the surface of the iron. Hence, even above 570 deg. C., the scales forming on enamelling irons are principally Fe_3O_4.

Oxygen Pressures of the Oxides of Iron at High Temperatures

The thermal equilibrium diagram referred to above, as it stands, gives no information concerning the oxygen pressures of the various oxides at high temperatures. Actually, in the study of systems containing iron oxides, the gaseous phase is all important, since the oxygen pressure exerts a determinative influence on the composition of the oxides. It can readily be shown from theory that, for each pair of the oxides that can co-exist in equilibrium with one another, there exists, at any temperature, a definite oxygen pressure at which they are both stable. Changes in the oxygen pressure cause a pick-up or evolution of oxygen, with consequent change in the composition of the oxides. The oxygen pressures of oxygen-saturated iron FeO and Fe_3O_4 are all much too small at ordinarily attainable temperatures to be measured directly. These phases are normally in equilibrium only with extremely low oxygen pressures such as exist in mixtures of CO and CO_2 at high temperatures, and their dissociation pressures can only be obtained indirectly by calculation. They have been studied by Matsubara,[6] Schenck and Dingman[4] and others.

In the case of oxide lying within the range of composition Fe_2O_3-Fe_3O_4, the oxygen pressures are directly measurable at high enough temperatures. The dissociation pressure of ferric oxide, for example, becomes detectable in the vicinity of 1,100 deg. C. The equilibrium conditions in this range of composition have been studied by several workers, and for several years past systematic investigations on the subject have been proceeding in the Metallurgy Department of the Royal Technical College, Glasgow.[7] The methods employed there have depended on the measurement of the oxygen evolved or absorbed by oxide of known composition in coming to equilibrium at given temperatures and oxygen pressures. This can be done in two ways: (1) by measuring the change in pressure resulting when the reaction is allowed to take place in a closed system, and (2) by measuring the change of weight undergone by the oxide in reaching equilibrium. The latter method, which has been found capable of wider application than the other, has been made possible by the successful development of a "high-temperature balance" by means of which samples can be weighed at temperatures up to 1,650 deg. C. and at any oxygen pressure up to 76 cm. of mercury. By these means the equilibria involved have been studied with the oxides in both the liquid and solid states.

The results obtained indicate that the reactions involved are truly reversible, whether the oxides

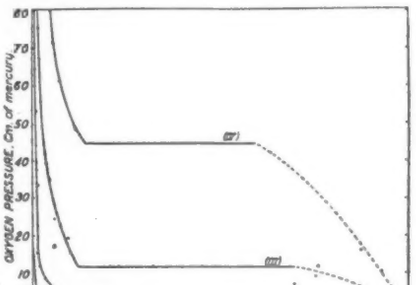

FIG. 2.—DISSOCIATION-PRESSURE/COMPOSITION ISOTHERMS FOR THE SYSTEM Fe_2O_3-Fe_3O_4.

(I) At 1,200 deg. C.; (II) 1,272 deg. C.; (III) 1,345 deg. C.; (IV) 1,415 deg. C.

are in the solid or liquid states, and it was concluded that, at any temperature and oxygen pressure, a true equilibrium is reached. The only exception to this was encountered in the case of the solid oxide if it were allowed to sinter to any great extent during dissociation at high temperatures. Subsequent pick-up of oxygen on cooling was then rather sluggish, and proceeded to completion only after very prolonged soaking. This was held to be due to physical rather than chemical reasons, however.

The dissociation pressure of ferric oxide was measured at various temperatures, and was found to increase rapidly and almost logarithmically with temperature. In the solid state the product of the dissociation is Fe_3O_4, which is, however, partially soluble in the residual Fe_2O_3, so that, not until a definite degree of dissociation of the original Fe_2O_3 has occurred, does a second solid phase appear in the oxide. Up to this point the system is divariant. When the amount of Fe_3O_4 formed is in excess of that required to form a saturated solid solution in the residual Fe_2O_3, a new solid phase appears which is a saturated solution of Fe_3O_4 in Fe_2O_3. The system then becomes monovariant, and the oxygen pressure, so long as the two solid phases

* Paper read before the Scottish Regional Conference of The Institute of Vitreous Enamellers last month, Mr. W. H. Whittle presiding.

are present, is a function of temperature only, and increases approximately logarithmically as the temperature increases. Further dissociation leads ultimately to the complete disappearance of the Fe_2O_3-rich solid solution, and the system becomes once more divariant. Fig. 1 shows in graphical form the variation with temperature of (*a*) the initial dissociation pressure of undissociated ferric oxide, and (*b*) the dissociation pressure of the two saturated solutions.

Fig. 2 shows, at various temperatures, how the dissociation pressure of the oxide varies with

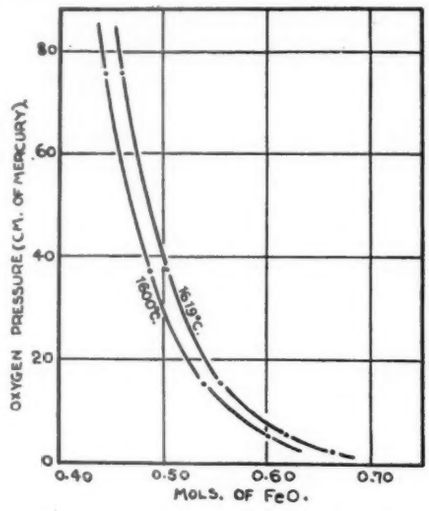

FIG. 3.—EQUILIBRIUM IN IRON-OXIDE MELTS. OXYGEN-PRESSURE/FERROUS-OXIDE ISOTHERMS.

composition at constant temperature. It will be seen that, as the concentration of Fe_3O_4 in the Fe_2O_3-rich solid solution increases, there is a rapid drop in the dissociation pressure of the oxide, which continues till the saturation limit is reached. So long as two solid solutions are present, the dissociation pressure at any temperature remains constant, due to the monovariance of the system. With the disappearance of the Fe_2O_3-rich solid solution, the dissociation pressure becomes once more a function of the composition of the oxide and shows a steady decrease as the composition of Fe_3O_4 is approached.

In the liquid state also ferric oxide dissociates to an equilibrium condition determined by temperature and oxygen pressure. Fig. 3 shows how the dissociation varies with oxygen pressure at constant temperature. To avoid making any assumptions as to the degree to which Fe_3O_4 may be stable in such melts, the dissociation has been expressed in terms of the FeO formed due to dissociation in a melt of what was originally one gram molecule of ferric oxide. It will be noticed that, according to the trend of the curves shown, a very high oxygen pressure would be required to prevent completely the dissociation of ferric oxide at these temperatures. It has been shown by extrapolation that a pressure of thousands of atmospheres would be necessary.

Behaviour of Fe_2O_3 in Presence of SiO_2 and CaO

The dissociation of ferric oxide in the liquid state has also been studied in the presence of silica and lime, singly and together, these being chosen as representative of a typical acid and a typical basic oxide respectively, and because they are both of frequent occurrence in systems containing iron oxides. It was found that in all cases a reversible equilibrium existed in the melts, the dissociation of the ferric oxide being governed as before by the temperature, and the oxygen pressure. The position of equilibrium, as measured by the ratio of Fe_2O_3 to FeO in the melts, was displaced by the presence of the other oxides to an extent depending on their concentrations and in a manner depending on their nature. Silica, for instance, caused a decrease in the equilibrium ratio Fe_2O_3/FeO, as shown in Fig. 4, while lime caused an increase in the value of the ratio, as can be seen from Fig. 5. When both lime and silica were present together, each acted in the sense characteristic of it, and the equilibrium ratio Fe_2O_3/FeO depended on the amount of each that was present. It is known that SiO_2 can combine with FeO in the solid state to form at least one stable silicate, while CaO, on the other hand, forms stable ferrites with ferric oxide. It seems probable, therefore, in view of the observations just made, that these compounds must also exist in the liquid state, and that the displacements of the equilibrium observed are the necessary consequences of the operation of the law of mass action. That this is so has been confirmed by attempts made to reproduce the theoretical curves by calculations based on the assumed validity of the ideal solution laws. (The results of these calculations are indicated by the broken lines in Figs. 4 and 5.) These indicate that ferrous silicate and the two calcium ferrites are all partially stable in the liquid melts. When both lime and silica are present together, the primary tendency appears to be to form calcium metasilicate, though appreciable amounts of ferrous silicate and the calcium ferrites may also be present.

The importance of this type of study has been realised by workers in a field very closely related to enamels. Studies on the ferric oxide content of glasses have been made by Turner and co-workers[8] in this country, and by Hostetter and Roberts[9] in America. It was found to be closely related to the chemical composition of the glass, a result which undoubtedly follows from considerations of the type outlined above.

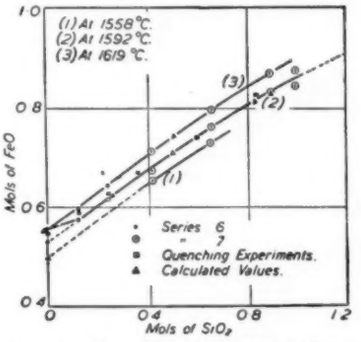

FIG. 4.—EFFECT OF ADDITION OF SiO_2 ON THE DISSOCIATION IN THE LIQUID STATE OF 1.0 MOL. OF Fe_2O_3 IN AIR.

Fig. 6 the relative stabilities of the three oxides of iron at high temperatures are indicated in terms of their dissociation pressure curves. The solid lines are based on experimental determinations, while the broken lines are calculated on theoretical considerations.

Mechanism of Gas-Oxidation in the Open-Hearth Steel Furnace

The knowledge summarised in the preceding sections is capable of wide applications in the fields of geophysics, ceramics, metallurgy and general high-temperature chemistry. A particularly important application is to certain of the reactions that occur in the open-hearth steel furnace during the refining process. It has been known for long that a considerable proportion of the oxygen necessary for refining comes from the furnace gases, passing through the overlying slag layer to the metal by a process of diffusion. This "gas-oxidation," as it is called, takes place as a direct consequence of the relationships that exist between iron and its oxides at high temperatures.

In the upper zone of the slag layer, *i.e.*, in the vicinity of the gas/slag interface, the slag is tending constantly to reach equilibrium with the gas over it. This means that ferrous oxide of the slag will tend to undergo oxidation to ferric oxide until the equilibrium value of the ratio Fe_2O_3/FeO, as determined by the temperature, the oxygen-pressure and the composition of the slag, is attained. At the slag/metal interface, on the other hand, where the slag is in direct contact with metallic iron, only FeO is stable. Hence continuous reduction of the ferric oxide of the slag to ferrous oxide takes place, accompanied by oxidation of metal to ferrous oxide.

Thus there is a continuous tendency for ferrous oxide to undergo oxidation to ferric oxide in the upper regions of the slag layer, and for ferric oxide to undergo reduction to ferrous oxide in the vicinity of the metal. As a result of these incompatible conditions at the upper and lower surfaces of the slag, a continuous cycle of reactions is set up within it, leading to a continuous diffusion of oxygen to the metal. With slags containing a predominance of basic oxides the effects of gas-oxidation are more prominent than with slags that are predominantly acid. This would be expected from the observed effects of lime and silica respectively on the stability of ferric oxide in the liquid state.

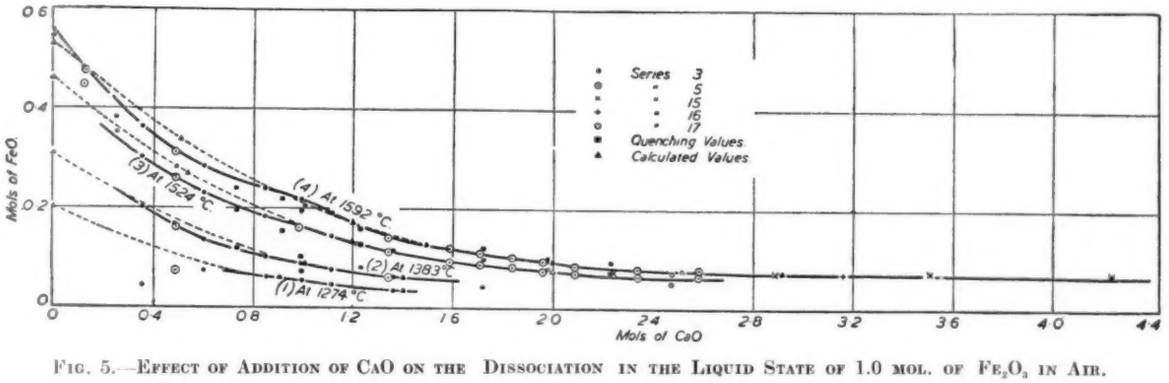

FIG. 5.—EFFECT OF ADDITION OF CaO ON THE DISSOCIATION IN THE LIQUID STATE OF 1.0 MOL. OF Fe_2O_3 IN AIR.

Part Played by Atmospheric Oxygen during the Enamelling of Iron

During the firing of the ground-coat enamel on iron and steel, a layer of scale first of all

forms on the metal before the enamel is fused. After fusion this appears to be rapidly dissolved by the enamel producing an enamel glass charged with iron oxides. The conditions that exist are, therefore, very similar to those that exist in the open-hearth furnace slag. Hence it might be predicted on physical chemical grounds that oxygen diffusion should take place through the enamel layer to the underlying metal. Such a prediction, being based on thermochemical considerations, could probably be made with certainty. The velocity of the process, however, which is all-important from the point of view of the practical application of the theory, could not be forecast, as it is dependent on many factors which cannot at the moment be completely assessed.

Within recent years researches by Dietzel and Meures[10] and by Kautz[1] have drawn attention to this aspect of the enamelling process, and these workers seem to have definitely established that such diffusion does actually take place, and with an appreciable velocity. The former workers investigated the effects of prolonged fusion on iron of enamels free from adhesion-producing oxides. They found that the reactions occurring after fusion of the enamel could be divided into three stages. During the first stage the initially formed scale (which normally at fusion had reached a thickness of 7 to 10 microns) dissolved in the enamel glass, giving it a green coloration. At this stage the iron oxide content of the enamel was mainly in the ferrous condition. During the second stage the total iron oxide content of the enamel increased, while, at the same time, the proportion of ferric oxide to ferrous oxide increased until at last a stage was reached when the enamel became saturated with Fe_3O_4, which began to separate as minute black crystals. At this time also a second scale began to form on the surface of the metal, and good adhesion of the enamel was obtained even in the absence of adhering oxides. During stage three ferric oxide crystals appeared and the enamel was over-oxidised.

The observations of Kautz confirmed these findings on the whole and elaborated them. He claimed that, for good adhesion, the initial scale must be completely removed by solution in the enamel glass. This begins as soon as the enamel fuses. At the same time the rate of supply of oxygen to the metal is slowed up by the intervening layer of enamel glass. Hence at this stage the rate of solution of scale from the metal surface is much more rapid than the rate at which it is forming, and so the scale tends to be completely removed. Meanwhile the iron oxide content of the enamel is continually increasing and with it the rate of diffusion of oxygen through the enamel glass. At last a stage is reached at which the rate of supply of oxygen to the metal is greater than the rate of solution of scale in the enamel and so a second scale begins to form. According to Kautz this scale adheres strongly to the metal on one side (he postulates a sort of solution bond since oxygen has appreciable solubility in iron) and to the enamel on the other.

Kautz found good adherence with most of his specimens when the new oxide layer had attained a thickness of approximately 3 by 10^{-5} in. as shown in his photomicrographs. The reason for the different functions of the first and second scale layers is attributed to the different conditions under which they are formed. The first scale is formed by the direct attack of atmospheric oxygen on the metal surface and consists mainly of Fe_3O_4. It has no marked adherence, and flakes off comparatively readily. The second scale is formed slowly since the layer of fused enamel regulates the supply of oxygen to the metal. It is very thin and is held to be mainly ferrous oxide. This idea has a certain degree of feasibility, since it is known that thin, carefully formed oxide films adhere strongly to many metals while thicker films do not, owing to disruptive forces within them.

The views of Kautz have not, of course, met with complete acceptance, which is as might be expected with so many different theories on adhesion in the field. Many authorities while quite ready to recognise the importance of the part played by oxidation in enamelling, are suspicious of the idea of a second oxide film, and attempts have been made to explain it away as superfluous. Lord,[11] for instance, does not consider it necessary though he is quite prepared to believe that the concentration of iron oxide reaches a high value—even to the point of saturation—in the enamel in the immediate vicinity of the metal surface. Dietzel and Meures[12] have suggested

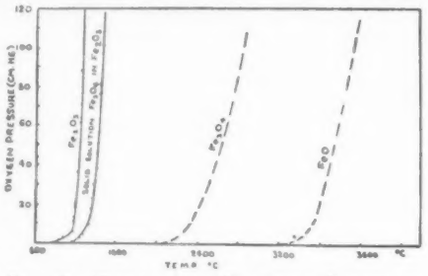

FIG. 6.—DISSOCIATION PRESSURE CURVES OF IRON OXIDES. SOLID LINES, EXPERIMENTAL DATA, WHITE, GRAHAM AND HAY. BROKEN LINES, BY CALCULATION.

another function of the iron oxides in this region of the enamel. They have shown that the presence of iron oxides in the glass increases the thermal expansion, and they found in the case of ground-coats investigated by them, that when these were normally fired to give strong adhesion, the concentration of the iron oxides at the interface was such as to make the thermal expansion of the enamel practically identical with that of the metal. They suggest, incidentally, that this is the reason why most successful commercial ground-coats have, initially at least, a markedly lower coefficient of thermal expansion than the metal to which they are applied.

The Function of the Adhesion-Producing Oxides

No theory of adhesion can be regarded as complete which does not take into account the action of the so-called adhering oxides. According to Kautz the function of cobalt oxide is two-fold: (1) It increases the solvent power of the

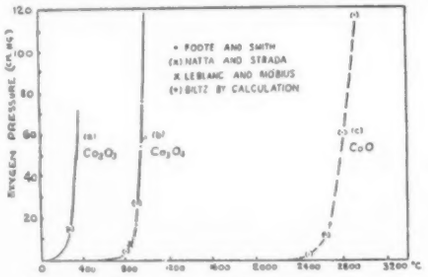

FIG. 7.—DISSOCIATION PRESSURE CURVES OF COBALT OXIDES.

enamel for the initial oxide scale, and (2) it facilitates the formation of the second oxide layer, presumably by speeding-up the rate of oxygen diffusion through the glass in some way. In the former connection, his photomicrographs appear to show that white cobalt-free ground-coats have very low solvent power for the scale, while in the presence of cobalt it is usually rapidly removed. In the latter connection it was found that adhesion was obtained with much shorter firing periods in the presence of cobalt, prolonged firing being necessary in its absence.

With regard to this second function of cobalt oxide, it is possible that it may itself be able to act as an oxygen carrier in the same way as iron oxide does. Like iron, cobalt has three oxides representing different degrees of oxidation, and there is a close similarity between corresponding states of oxidation of the two metals. The stability relationships between the oxides of cobalt have not been so extensively studied as have those of the oxides of iron, but Fig. 7 summarises the available data, experimental and theoretical, on the dissociation pressures of the three oxides at high temperatures. Quantitatively the values indicated cannot be accepted too rigorously, but they can probably be taken as indicating the relative stabilities of the oxides. It will be seen that a composition approximating to Co_3O_4 will be stable in air at enamelling temperatures, so that in the fused enamel glass the degree of oxidation of the cobalt will, presumably, tend to this. In contact with iron, however, reduction will take place to CoO, or even possibly to metallic cobalt in part, since CoO appears to have less stability than FeO, as can be seen by comparing Figs. 6 and 7. This latter fact, incidentally, may possibly explain the frequently reported precipitation of metallic cobalt from cobalt oxide ground-coats near the surface of the iron. It will thus be seen that conditions are suitable for the development of an oxidation and reduction cycle of the type previously discussed involving the oxides of cobalt.

It is further significant that nickel and manganese, the oxides of which are also used to promote adherence, should each have several oxides, and that these should be comparable in their stabilities and in their relationships to one another to the oxides of iron. The oxides of these metals also, therefore, should be capable of functioning as oxygen carriers, and it seems possible that this may be one of the chief functions of the adhering oxides. The question arises as to whether the small amount of cobalt oxide generally employed in ground-coats could make a very big contribution to the oxygen-flow through the enamel. It is possible that its action may be semi-catalytic in nature, and that it accelerates the iron oxide reactions in the enamel.

Conclusion

There seems little room for doubt that the oxides of iron play an important part in the reactions that occur when iron is being enamelled. Whether or not adhesion is dependent on their presence in the ground-coat in the vicinity of the metal surface, it is certain that by their presence they will materially affect the properties of the enamel. It is of some importance, therefore, that the enameller should know something of the conditions governing the formation of these oxides, and of the reactions in which they may take part while the enamel is being fused and afterwards.

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10 Dietzel and Meures: Journ. American Ceramic Society, 1935, 14, p. 35.
11 Lord: Journ. American Ceramic Society, 1937, 20, p. 111 *et seq.*
12 Dietzel and Meures: Journ. American Ceramic Society, 1935, 14, p. 37.

Jugoslav Steel Control

The Jugoslav Government has, by decree, brought about the merging of the country's collieries and iron ore mines and the Zenica iron and steel works to form a national concern under the title of Jugoslav Steel with a capital of approximately £3,000,000. All the shares will be owned by the State, which now controls the country's entire iron and steel production.

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UNEMPLOYMENT..

£121,000,000 more imports than a year ago! Great Britain is buying far more than she sells..... On the official figures of the Department of Overseas Trade the balance on the wrong side for 1937 was £432,000,000; for the year 1936 it was £311,000,000. That is the gap between imports and exports.

The best way to avoid recession in trade, loss of profit and subsequent unemployment, is to check this overbuying with its consequent unbalancing of trade. This can be accomplished in part by **not** buying foreign enamels which are precluded from sale in other countries by high tariffs. BUY BRITISH instead and BUY BLYTHE for preference.

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The Week's News in Brief

Trade Talk

THE NEW FACTORIES ACT, which was the subject of a recent series of articles in the JOURNAL, came into force last Friday.

FALKIRK TRADE HOLIDAYS commenced on July 1 with the closing down of foundries and factories in the town and district for a week.

BAKER PERKINS, LIMITED, of Peterborough, are carrying out extensions to their foundry and are building a new warehouse office and other offices.

THE BELLOW MACHINE COMPANY, LIMITED, have opened a foundry at their premises at Grafton Street, Leeds. The firm produces special machinery for the clothing and allied trades.

ONE HUNDRED POUNDS is being offered in prizes to amateur film makers by the National "Safety First" Association, which will use the prize-winning efforts in its lecture campaign.

AN ENDEAVOUR was made last Thursday to settle the dispute at the works of W. & J. Lawley, Limited, Britannia Foundry, West Bromwich, where 85 moulders ceased work over a month ago. The negotiations were unsuccessful.

THE BURNTISLAND SHIPBUILDING COMPANY, LIMITED, Burntisland, have received a contract from the Fulham Borough Council to build two self-trimming colliers of the Thames up-river type, each of 2,400 tons deadweight capacity.

BY DECREE effective May 15 last, Japan has prohibited the use of pig-iron (without special permission) in the manufacture of numerous cast-iron domestic articles, such as rain-water tanks, bridge railings, lamp posts, manhole covers, and hand rails.

A PARTY of about 30 Danish students of chemical engineering, from the Royal Polytechnic High School, Copenhagen, have been visiting works in various parts of the country. They were entertained to tea by the Institution of Chemical Engineers in London on Wednesday of last week.

THE BUSINESS of Westoby & Rawstron, iron and steel merchants, 328, Royal Exchange Buildings, Manchester, 2, has now been transferred to Mr. J. E. Rigby, who has been associated with the firm since it was established over 30 years ago, and it will continue under the same title. Debts will be received and paid by Mr. Rigby.

PORCELAIN ENAMEL FRIT is now being produced by the Endless-Flow process at the plant of the Ferro Enamel Corporation in Cleveland. The company has built a large new storage and mixing building, an intricate conveyor system, four patented continuous smelters and a large finished storage warehouse for storing the finished frit.

THE INCREASING demand for material by the Turkish armaments factories and the need for developing the steel industry, due to the construction of the blast furnaces at Karabuk, have induced the Turkish Government to attempt to salvage about 200,000 tons of scrap from steamers which at various periods have been sunk in the Golden Horn, the Bosphorus and in the Dardanelles, as well as round the Turkish coasts. British concerns are likely to co-operate in the salvage of these wrecks, it is stated.

ABOUT 95 employees of the Skinningrove Iron Company, Limited, have received notice to terminate their employment owing to the necessity for closing down another blast furnace in view of the reduced demand for Cleveland pig-iron. The company was formerly operating four blast furnaces, one of which was closed down on December 30 last, so that the closing of another furnace will leave only two in blast. This further curtailment of output is due to the accumulation of pig-iron stocks on Tees-side. Since the beginning of the year, ten blast-furnaces have been closed down in the North-East Coast area.

ATTENTION was drawn at a meeting of Walsall and District Chamber of Commerce last week to the increase in German imports, particularly of small metal castings, which it was stated, was seriously affecting a number of local firms. Many thousands of pounds worth of this class of goods was reaching the Midlands. It was true there was a duty of 33⅓ per cent. on castings of 7 lbs. and upwards, but on lighter castings the duty was only 20 per cent. Labour costs in Germany were about 40 per cent. lower than in this country and, in addition, the German Government paid a subsidy. It was decided to make representations to the Import Duties Advisory Committee.

THE DUKE OF KENT, during his tour of Sheffield on Wednesday of last week, visited the Atlas Works of Thomas Firth & John Brown, Limited, where he arrived with Mr. A. J. Grant (managing director) and Dr. W. H. Hatfield and Mr. Edward Dixon (directors). On arrival at the Vickers Works of the English Steel Corporation, Limited, the directors and a number of executives were presented to the Duke by Commander Sir Charles Craven, chairman and managing director. Among those presented were Mr. A. B. Winder and Mr. Alex Dunbar (directors and joint general managers), Mr. F. Pickworth (director and secretary), Rear-Admiral J. F. C. Paterson (special director), and Mr. G. E. G. Gilfillan (works superintendent). During his visit the Duke saw the tapping of a 60-ton acid open-hearth furnace.

Personal

SIR ALEXANDER GIBB is to receive the honorary degree of LL.D. at the University of Edinburgh on July 20.

MR. ALEXANDER SMITH, a retired moulder, of Grahamsdyke Street, Falkirk, last week celebrated his golden wedding.

THE EARL OF DUDLEY has been appointed an Officer of the Venerable Order of the Hospital of St. John of Jerusalem.

SIR JOSIAH STAMP, President of the London Midland & Scottish Railway, who was created a baron in the Birthday Honours List, has chosen as his title Lord Stamp of Shortlands.

MR. E. G. SARSFIELD HALL, whose resignation from the position of District Commissioner for the West Cumberland Special Area was recently announced, has joined the board of the Workington Iron & Steel Company, Limited.

MR. W. G. MACPHERSON, Glasgow representative of the United Steel Companies, Limited, was on June 30 presented by his friends with a gold watch, wallet of notes and other gifts on the occasion of his retirement after 50 years in the Scottish steel trade. Mr. Macpherson played for several years with Queen's Park F.C.

SIR STEPHENSON KENT and MR. ALLAN MACBETH have joined the board of Guest, Keen & Nettlefolds, Limited. Sir Stephenson Kent has been intimately concerned with the direction of the Powell Duffryn group of collieries, in which the company is largely interested. Mr. Macbeth is managing director of the Exors. of James Mills, Limited, of Bredbury, Stockport, and chairman of Guest, Keen, Williams, of India.

Wills

PARTINGTON, WILLIAM, of Manchester and Salford, engineer and machinery merchant	£12,350
WESTALL, J., a director of Kendall & Gent (1920), Limited, Gorton, Manchester	£9,282
ENNIS, LAWRENCE, formerly managing director of Dorman, Long & Company, Limited, and a director of several other companies	£37,457
WHITEHEAD, L. D, chairman and managing director of the Whitehead Iron & Steel Company, Limited, and a director of other companies	£337,265

Obituary

MR. S. LOVERIDGE, for many years a director of T. & C. Clark & Company, Limited, chemical plant manufacturers and ironfounders, of Wolverhampton, died last week at the age of 84.

MR. JAMES W. ELLIS, chairman of James W. Ellis & Company, Limited, iron and steel merchants, of Newcastle-upon-Tyne, and a director of the North Eastern Marine Engineering Company, Limited, of Wallsend, has died in his 83rd year.

MR. ROGER S. BROWN, who was at the Atlas Works of Thos. Firth & John Brown, Limited, for over fifty years, died at Sheffield on June 27, at the age of 75 years. A nephew of the late Sir John Brown, Mr. Roger Brown entered the Atlas Works in October, 1875. After going through the steel department, drawing office, and engineers' department, he went to Davy Bros. for a short time to get more experience, and on returning to the Atlas Works he occupied the position of chief draughtsman of the company for a number of years. In 1897 he was appointed to the test house and after that date continued his association with the inspecting engineering branch until 1931, when he retired.

Company Meeting

The annual meeting of F. H. Lloyd & Company, Limited, was held in Darlaston, on June 29. MR. F. J. HEMMING (chairman) said that output and earnings had increased substantially. For the third year in succession the rate of production was a record. Notable among the additions to their equipment had been the introduction of an electric melting furnace, together with heat-treatment furnaces and foundry equipment. As a result, they were able to offer to their customers steel castings of such processes as they desired and extend their operations usefully into the supply of alloy steel castings, for which there was a growing market. Their industry was organised and affiliated to the British Iron and Steel Federation, a factor which should make for stability in the future. During the past few months there had been some recession in trade, but he thought they shared the effect created by much overbuying in the middle of last year and that when stocks were lower, a return to activity would take place. Their order-book was satisfactory, and the delivery position much improved. They looked forward to the future with confidence.

Company Reports

Aveling-Barford, Limited.—Dividend of 8 per cent., tax free.

A. & J. Main & Company, Limited.—Net profit for 1937, after depreciation, £30,885; brought in, £1,162; preference dividend, £4,463; ordinary dividend of 7 per cent., £4,538; to preference share dividend account, £6,041; to general reserve, £15,500; carried forward, £1,455.

Bradley & Foster, Limited.—Trading profit for the year ending March 31, £26,715; taxation, £6,736; to depreciation reserve fund, £2,613; brought in, £4,716; to general reserve fund, £10,000; interim dividend on ordinary shares at 4 per cent. actual, £2,305; final dividend on ordinary shares at 4 per cent. actual, plus a bonus of 2 per cent., £3,343; carried forward, £6,434.

Contracts Open

Johannesburg, August 8.—539 tons of steelwork, etc., for the South African Railways and Harbours Administration. The Department of Overseas Trade. (Reference T. 23,600/38.)

Cheadle, July 13.—Providing and laying 3,260 yds. of 4-in. spun-iron main and 200 yds. of 3-in. spun-iron main, etc., for the Rural District Council. Mr. A. P. Hancock, surveyor, Council Offices, Cheadle. (Fee £2 2s., returnable.)

Zarabe.—Turbo-electric power plant, boilers, compressors, etc., for coal mine, for the Ministry of Industry and Mines of Iran. The Commercial Attaché to the Imperial Iranian Legation, Ling House, 10-13, South Street, London, E.C.2.

Rumanian Steelworks Report

S.A. Roumaine Usines Métallurgiques Réunies, Titan, Nadrag, Calan, the Rumanian iron and steel concern, in its 14th annual report, for 1937, calls attention to the higher prices which were necessary for iron and steel products in order to cover the steep increase in taxes made by the Government. Last autumn, the Government decided to give special consideration to the metallurgical industry in view of the heavy burdens it already had to bear, and exempted it from taxes on raw materials and particularly on semis, one of the staple products of the concern. But the exemption did not operate until last spring, after 75,000 tons had been imported. Nevertheless, this exemption and the decline in scrap and semis prices have enabled iron and steel prices to be substantially reduced for 1938 in the hope of stimulating trade. Taxation last year took 273,827,000 lei, or more than 25 per cent. of the total sales of the concern. Net profit was 97,612.585 lei, against 74,852.387 lei in 1936, and was the highest ever recorded by the company. The dividend has remained unchanged at 15 per cent. In the 14 years of its existence the company has never paid less than 9 per cent. on its capital, and that only once, in 1931. At the end of 1937 the capital was raised from 400,000,000 lei to 500,000,000 lei, on which the 15 per cent. dividend is paid. Production in the year included 19,800 tons of pig-iron at the Calan blast furnaces and 55,000 tons of steel at the Ferdinand steelworks. (Current rate of exchange: £1 = approx. 670 lei.)

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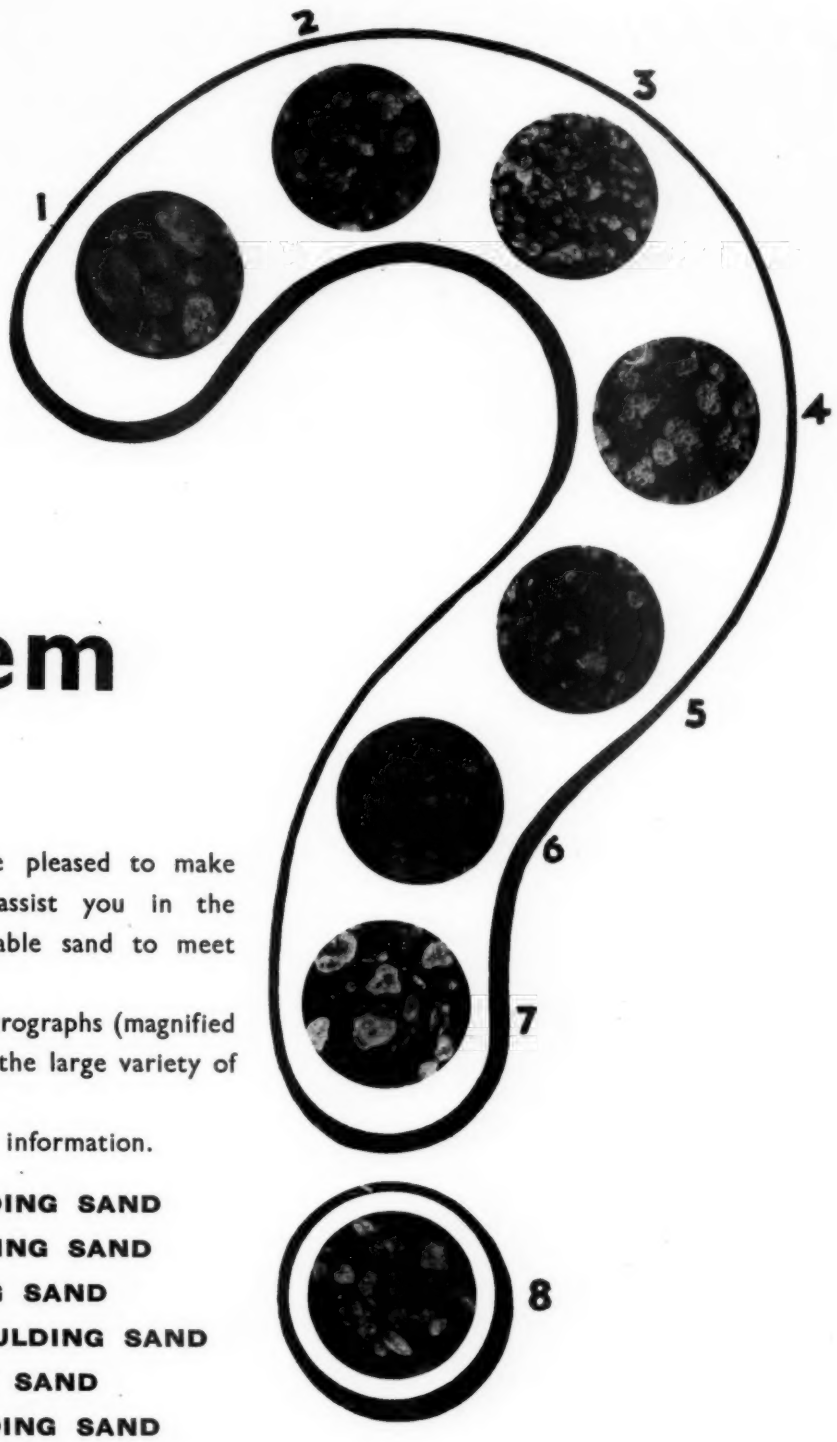

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MIDDLESBROUGH OFFICE : Halifax Bldgs., Exchange Place, Telephone : Middlesbrough 3313. Telegrams : "Genefax, Middlesbrough." (Mr. J. A. Williams).

BIRMINGHAM OFFICE : 5, Lower Temple Street, Telephone : Midland 6376. Telegrams : "Genefax, Birmingham." (Mr. G. Griffiths).

Raw Material Markets

Pig-iron consumers continue to draw but slowly on their stocks and prospects of an early resumption of business are remote. It is likely to be a month or so before there is any material expansion of activity.

It is understood that the Stanton Ironworks Company, Limited, has resigned from the Central Pig-Iron Producers' Association and the Foundry Pig-Iron Producers' Association. The company, apparently, holds the view that the current prices of pig-iron are too high. It is believed that the British producers' decision to maintain quotations at existing levels up to the end of the year was made after strong recommendations by the Import Duties Advisory Committee. The Stanton Ironworks Company, Limited, is a large producer of foundry pig-iron, and its decision to withdraw from the associations is of considerable interest both to consumers and to other producers of pig-iron. The company, of course, consumes a large proportion of its pig-iron output in its own pipe foundries, but it disposes of a big tonnage in the open market. The decision cannot have much immediate effect on the market, because six months' notice of withdrawal has to be given. By the time that period has expired the Pig-Iron Producers' Association will have announced its price proposals for next year, but the Stanton Company can presumably book orders for delivery after the end of the year at what prices it may decide. What effect the rebate scheme will have on the company's sales, if it does definitely withdraw from the associations at the end of the six months, is difficult to say. The scheme was primarily intended to keep out foreign iron, but its provisions apply to purchases from any non-associated maker.

Pig-Iron

MIDDLESBROUGH.—Although production of pig-iron in this district has been drastically cut from the level of last year, producers' stocks still remain heavy, while consumers, also, are able to satisfy their requirements from supplies on hand. Some consumers are still taking up contract deliveries of Indian iron, which is allowed to enter the country without payment of duty, while there are also heavy tonnages of foreign iron at consumers' yards, although no new transactions are now being made. New business in hematite, also, is very quiet, and current supply more than accounts for the demand. Inquiries from abroad have almost ceased completely and shipments have now reached very low levels. Prices for home business, including delivery up to the end of the year, are based on East Coast hematite mixed numbers at 132s. 6d. on the North-East Coast, 138s. in Sheffield, 140s. 6d. in Manchester, and 143s. 6d. in the Midlands.

LANCASHIRE.—Signs that some of the light-castings foundries were rather better situated for work have recently been noticeable, but there appears to be little justification for believing that there is going to be any real expansion in this section in the near future, at any rate. Only the machine-tool and the heavy electrical concerns are working on anything like a satisfactory basis. Makers of textile machinery are still operating on the quiet side, while most of the jobbing founders are not receiving a normal share of orders. On the whole, consumers are unwilling to look beyond the end of September for further supplies. For delivery in the Manchester price zone, Derbyshire and Staffordshire brands of No. 3 foundry iron are quoted on the basis of 114s. per ton, with Northamptonshire at 112s. 6d. and Derbyshire forge iron at from 111s. to 113s. The price of Scottish foundry iron is 137s. 6d., but there is little business being transacted. Hematite is quiet at 141s. for West Coast mixed numbers, and 140s. 6d. for East Coast hematite.

MIDLANDS.—The foundry-iron market in this area remains very quiet. New business is difficult to procure, as most consumers are in possession of heavy stocks. Orders to the consuming plants do not seem to be expanding to any extent and many concerns, especially the light-castings makers, are on short time. Low-phosphorus iron is fairly well taken up and the consumption of this material is increasing. The demand for hematite is small and most users are covered for several months ahead by their existing stocks. The tonnage of forge iron changing hands is small, users generally being in possession of adequate supplies for their limited requirements.

SCOTLAND.—The annual holidays are now being taken in this area, and, consequently, what new business there is to be placed is suspended. Buyers are not anxious to make contracts too far ahead at present, as they realise that there is no financial benefit to be obtained from so doing. As contracts expire small tonnages are bought for early deliveries. No. 3 foundry iron is quoted at 118s., f.o.t. furnaces, with No. 1 at 120s. 6d. Local steelworks have no need to take up further supplies of iron, as they are well covered in this respect. Hematite mixed numbers are quoted at 133s., Scottish basic 107s. 6d., and English and Indian basic 100s., all less 5s. per ton rebate.

Coke

Foundry coke prices will remain unchanged up to the end of the year at 50s. 6d. for best Durham coke and from 50s. 6d. to 60s. for Welsh, these quotations including delivery to Birmingham and Black Country stations. Only small tonnages are changing hands from week to week.

Steel

The usual quiet summer conditions prevail in the steel market, and there is considerable irregularity in the rate of operations now ruling in the different departments. Business in the semi-finished steel department has been affected by the heavy stocks which were accumulated early in the year, and have not yet been absorbed. Recently, however, there have been indications that some consumers are again taking an interest in the market. This section of the industry is working at below capacity, and it is not expected that the demand will fully revive until the early autumn. The brighter tone which was noticeable recently in the finished steel department has been maintained, but there has been no important improvement in the volume of new business. The heavy-steel works are provided with orders sufficient to keep them occupied for some time, and recently the lighter sections of the industry have experienced a broadening in demand. Export business continues to be restricted by adverse trading conditions and overseas consumers are pursuing a policy of buying from hand to mouth.

Scrap

The iron and steel scrap market continues to be very dull. In many cases, consumers are unable to take up supplies already under contract, while additional contracts are quite out of the question. Many of the steelworks are in this position and there does not appear to be any likelihood of a material improvement in the near future.

Metals

Largely as a result of the continued cheerful advices from Wall Street, the non-ferrous metal markets in London have remained bright during the past week. Many consumers have deemed it advisable to take up additional supplies in face of the higher quotations.

Copper.—Some quite good buying has been done recently. Most users of the metal are fairly well covered, although not sufficiently well to keep out of the market for a long period. On the Continent, French business has been seriously hampered by the widespread strikes at metal works in the Marseilles area. A fair interest continues to be shown both by Germany and Japan. With regard to the former, the recently concluded Anglo-German debts agreement is likely to make trade between the two countries considerably easier.

Metal Exchange quotations were as follow :—

Cash.—Thursday, £37 17s. 6d. to £38; Friday, £38 1s. 3d. to £38 3s. 9d.; Monday, £39 11s. 3d. to £39 12s. 6d.; Tuesday, £40 2s. 6d. to £40 3s. 9d.; Wednesday, £39 16s. 3d. to £39 17s. 6d.

Three Months.—Thursday, £38 3s. 9d. to £38 5s.; Friday, £38 7s. 6d. to £38 8s. 9d.; Monday, £39 17s. 6d. to £39 18s. 9d.; Tuesday, £40 7s. 6d. to £40 8s. 9d.; Wednesday, £40 2s. 6d. to £40 3s. 9d.

Tin.—According to the returns compiled by Mr. W. H. Gartsen (Henry Rogers, Sons & Company), there was a small increase in the total visible supply of tin on June 30, as compared with May 31. The total at the end of last month was 27,512 tons, against 26,308 tons at the end of the previous month. These figures include the carry-overs in the Straits Settlements and at the Arnhem (Holland) smelter.

The increase of 1,204 tons in the visible supply did not react unfavourably on the market, although it was a rather higher figure than had been anticipated. Business has not been particularly good this week, but the tone of the market is maintained. The American market remains quiet; tinplate mills are now operating at under 40 per cent. of normal capacity.

Official quotations were as follow :—

Cash.—Thursday, £189 5s. to £189 10s.; Friday, £188 2s. 6d. to £188 5s.; Monday, £194 to £194 10s.; Tuesday, £194 to £194 10s.; Wednesday, £193 5s. to £193 15s.

Three Months.—Thursday, £190 to £190 5s.; Friday, £189 2s. 6d. to £189 7s. 6d.; Monday, £195 5s. to £195 10s.; Tuesday, £195 5s. to £195 10s.; Wednesday, £194 10s. to £194 15s.

Spelter.—This market has become quite active and some fair tonnages have recently changed hands. Brassmakers, especially, are working at a good level, but galvanising concerns remain quiet. There has again been a revival of talk concerning the Zinc Cartel, but when previous efforts are taken into consideration it is most unlikely that anything will come of the present negotiations. The American Bureau of Metal Statistics reports that the world's output of zinc in April totalled 140,759 short tons, against 150,489 tons in March.

Daily market prices :—

Ordinary.—Thursday, £14 1s. 3d.; Friday, £14 5s.; Monday, £14 3s. 9d.; Tuesday, £14 8s. 9d.; Wednesday, £14 7s. 6d.

Lead.—Chiefly owing to the firmer tone on Wall Street this market has maintained its strength. The outlook is still rather uncertain, as buyers are only taking up small quantities for early delivery.

Day-to-day quotations :—

Soft Foreign (Prompt).—Thursday, £15; Friday, £15 1s. 3d.; Monday, £14 18s. 9d.; Tuesday, £15 5s.; Wednesday, £15 6s. 3d.

Scrap.—Small tonnages only are changing hands and consumers are still refraining from buying forward. Price movements have been in an upward direction this week.

Approximate selling prices for old metal :—New aluminium cuttings, £73; rolled, £57; cast, £28 to £29; foil, £88. Copper, £34 to £37; braziery, £30 to £31. Brass (clean), £21 to £25. Zinc, £9. Lead, £13 10s. Gunmetal, £37 to £39.

Publication Received

Nickel-Copper-Chromium Austenitic Cylinder Liners. Issued by Harold Andrews Grinding Company, Limited, Bristol Road, Birmingham, 5.

This rather unusual type of publication takes the form of a technical Paper written by Mr. G. Williams. He first summarises the position as to "corrosion *versus* mechanical wear" controversy, and follows up this by studies of surface chemistry, boundary lubrication and dry wear. Only passing references, mainly as captions beneath pictures and as footnotes, are made to the firm's own productions. Illustrations are included of the foundry—James & Company (B'ham), Limited—which supplies the castings from which the issuing house make their cylinder liners. They are made from cupola-melted, electric furnace refined and centrifugally-cast material.

A Fine Aluminium Wire

The Aluminium Union, Limited, are about to exhibit at the Glasgow Empire Exhibition a phenomenally small aluminium wire. It is said to be so fine that 10,000 pieces laid side by side would measure only 1 in. in width and that 20 ozs. of it, sufficient to encircle the world, would cost £101,000,000. The wire weighs 0.000000009246 lb. per ft. and has a diameter of $\frac{1}{10000}$ in., 600 of the wires being equivalent to the thickness of one human hair. The wire is invisible to the naked eye, and has to be observed through a high-powered microscope.